Some Essentials of Physics

Seymour & Wilson

SOME ESSENTIALS OF PHYSICS

BY

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PREFACE.

The purpose of this book is to guide the pupil in his efforts to know more of nature and her phenomena.

No experiment or suggestion is offered that has not been repeatedly tested in class work.

The time has passed for the Experimental Lecture Course before young people anxious to do just such things themselves.

Only one way seems open to the Science Student, *i. e.*, Nature's Way—by experience,

The one thing to do more than all others in all our schools, is to beget in our pupils the power to think accurately—persistently.

The next most important thing to acquire is clear, truthful expression.

All true work in science is especially helpful on these points.

The description of the experiment, its phenomena and proof, are *carefully omitted.*

It is hoped the cuts and statements concerning them will prove plain enough to show the pupil what to do, and give some hint as to how to do it.

The object has been to state and show the essentials of the topic. Hence it is presumed the library or teacher's desk is supplied with fuller texts on the subject.

The teacher must precede his pupils in all experimental work. He must be sure that he has worked the ground all over before directing others.

Success will be assured if the teacher can create in the minds of his pupils a spirit of investigation, if he can challenge them by questions, by drawings, to sharpest thinking—and by skillful handling of the class use the friction of one mind upon another as a stimulus to quick insight.

A student who successfully performs one experiment, clearly describing it and logically stating its phenomena and what it proves, has gained more power than he could ever acquire by seeing others do it.

Certain topics are outlined by carefully prepared definitions, drawings and statements—others are given in outline without comment.

It is hoped the simple character of the drawings will lead to their reproduction.

Some of them are from the valuable works of Atkinson, Lodge, Shaw, Poyser, Avery, Hopkins, Deschanel, Silliman, Mendenhall, and Gage.

These drawings, with many original ones, are from the pen of the artist, Miss Marie Pioda, Santa Cruz, Cal.

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WASHINGTON WILSON.

CHICO, CALIFORNIA,
Jan. 1, 1893.

INDEX.

MECHANICS.

CHAPTER I.

THE LEVER.

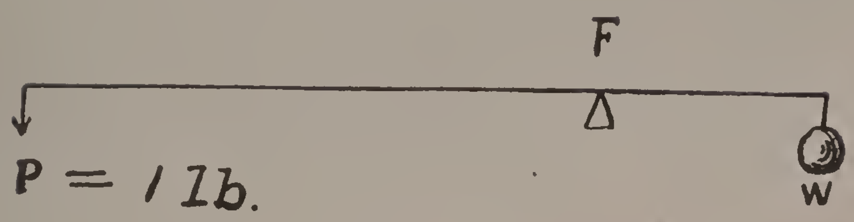


FIG. 1.

With suitable stick, weight, and rest, illustrate the above drawing.

Explain the terms used and point them out in the illustration.

By measurement, and from the text-book, determine the unknown weight.

Disturb the equilibrium of the lever and note the relative distances through which the power and weight move. Note also the relative velocities of each.

From the above experiments complete the following proportions: 1) P : W :: ? : ?, 2) Dist. W moves : Dist. P moves :: ? : ?, 3) V. of P : V. of W :: ? : ?.

Change the completed proportions to equations.

Notice that the ratio between the distances or velocities of power and weight is the ratio between **them**, also.

In the affairs of life the lever is a material one.

The material lever is a rigid bar moving about a support called the fulcrum.

In all problem work, the lever is mathematical.

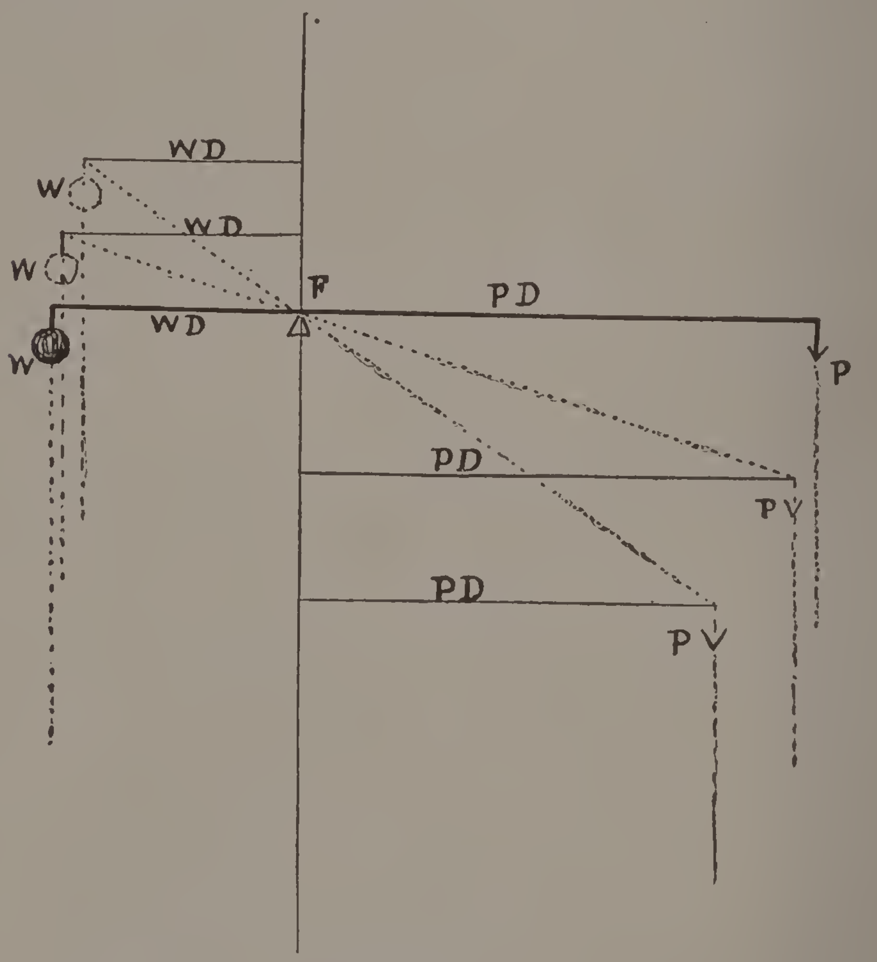
A mathematical lever is a line free to move about a point.

FORMULA FOR TERMS. P = Power. F = Fulcrum. PD = Power-distance. W = Weight. L = Lever. WD = Weight-distance.

The power-distance is the perpendicular distance from the fulcrum to the line along which the power acts.

The weight-distance is the perpendicular distance from the fulcrum to the line along which the weight acts.

In applying the mathematical lever to the material one, an error arises, viz: the difference in the weight of the arms, whatever their position. Thus,—



DRAWING A.

From the above drawing it appears that the power and weight distances change with the position of the lever.

All measurements are from the fulcrum.

The fulcrum is a point or line about which a lever turns.

There are three orders of the lever:

First order. The F is between the P and the W.

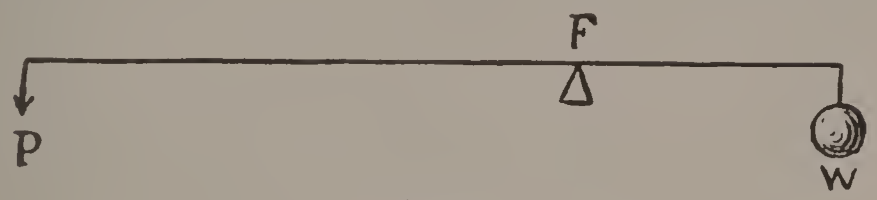


FIG. 2.

Second order. The W is between the F and the P.

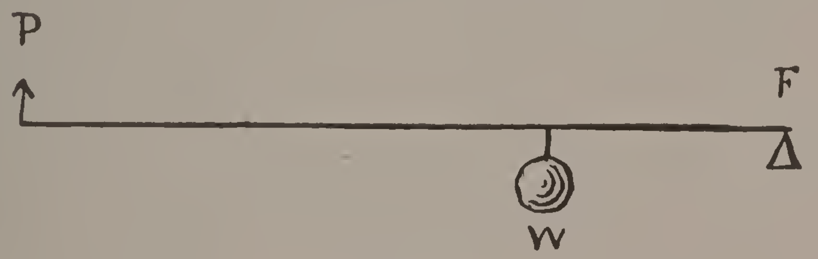


FIG. 3.

Third order. The P is between the F and the W.

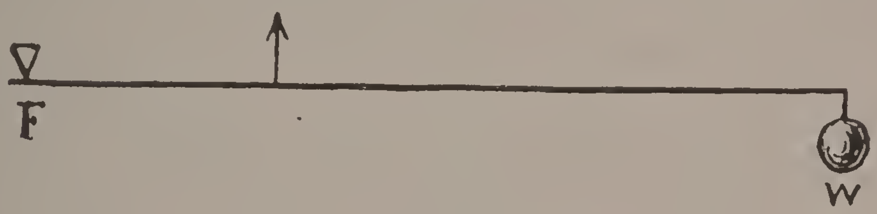


FIG. 4.

The first and second orders of levers effect an exchange of velocity for intensity. These orders of levers appear in many simple inventions in which it is desired to gain power at a loss of time or velocity. Levers of the third order effect an exchange of intensity for velocity, always at a loss of power. This is strikingly illustrated in the locomotion and flight of animals.

Classify: Crowbar, steelyard, wheelbarrow, sugar

tongs, nutcracker, scissors, sheep shears, transom lift, lemon squeezer, desk seat, pump handle, pincers, claw hammer, store truck, and door. Show how the last may illustrate each of the orders of levers.

A general formula for the solution of all problems on the lever is:

$$P \times PD = W \times WD.$$

This, however, considers the lever as statical, and as such it may be better understood as illustrating the law of the

MOMENTS OF FORCE. A moment of force is the product of the numbers representing the power or weight and the perpendicular distance of the same from the fulcrum. Hence the solution of all problems on the lever calls for an equality of the moments of force. Further, any three of the elements of the lever being given, the fourth can be found. Before any motion can result, the equilibrium of the lever must be disturbed.

ILLUSTRATIVE PROBLEMS.

1. In a lever 8 ft. long, a power of 6 lb. will balance what weight 6 in. from the fulcrum?
2. How much power will balance one ton on a 12-ft. lever with the fulcrum 3 in. from the weight?
3. Where place the fulcrum so that a power of 2 lb. may balance 100 lb. on a lever 9 ft. long?
4. A and B carry a 10-lb. salmon on an 8-ft. pole. The fish is 6 in. nearer A than B. What does each carry?

A PRACTICAL PROBLEM.

Three men wish to carry an equal weight of a stick of timber of uniform size and density. Where place a cross-lever for A and B, C being at the end of the stick?

EXPERIMENT. Secure a steel rod of uniform size and of convenient length. On each of two scales that

turn easily at the weight of a grain, balance a narrow-edged support.

Load one of the scales with one-third and the other with two-thirds of the weight of the rod. Place one end of the rod on the support of the scale bearing one-third its weight. Adjust the other scale and its support so that both scales will be in equipoise.

Upon measurement it will be found that the support bearing the greater weight is at a point one-fourth the length of the rod from its end.

SOLUTION. Consider the stick a mathematical lever with its weight massed over a fulcrum at its center.

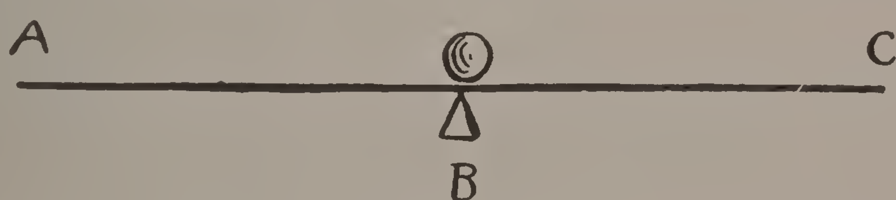


FIG 5.

It is required to distribute this weight so that its one-third shall be at C and its two-thirds at some point between A and B, the equilibrium remaining undisturbed.

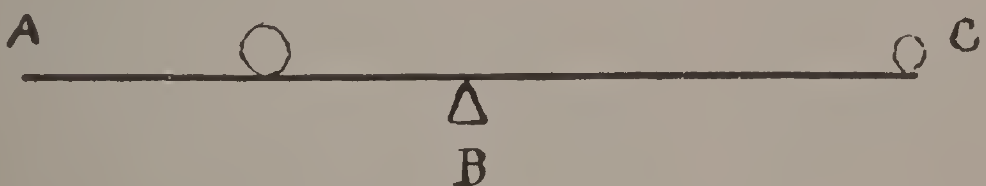


FIG. 6.

The lever is of the first order.

Since the ratio between W and P is 2, the power arm is twice the weight arm.

The power arm is one-half the length of the stick. The weight arm is therefore one-fourth the length of the stick.

The cross-bar must be placed one-fourth the length of the stick from its fulcrum.

Where should the cross-lever be placed for A and B to carry three-fourths of the weight? In a manner similar, the position will be found at one-sixth the length of the stick from its fulcrum. Give the solution.

THE COMPOUND LEVER. A compound lever is a combination of simple levers.

The weight for one lever becomes the power for the next. Thus:

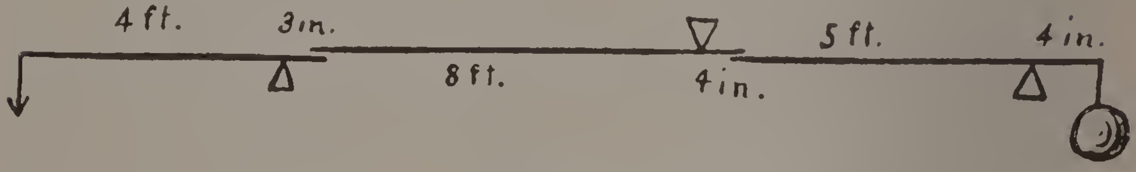


FIG. 7.

What power is required to disturb the equilibrium?

MISCELLANEOUS PROBLEMS.

1. L = 20 ft., P = 100 lb., W = 400 lb., F = ?

2. W = 2000 lb., L = 30 ft., F is 6 in. from end, P = ?

3. L = 36 ft., W = 1000 lb., P = 25 lb., PD and WD = ?

4. How long is the lever if 500 lb. balance 40 lb. 6 in. from the fulcrum?

5. What are the P and W distances if 16 lb. balance 400 lb. on a 20-ft. lever?

6. The oar of a boat is 8 ft. long. The hand is 2 ft. from the row-lock. Man and boat weigh 600 lb. Give P.

7. Two weights, 5 lb. and 7 lb., balance each other on the extremities of a lever 10 ft. long. Where is the fulcrum?

8. Four weights, 2, 4, 8, and 6 lb., **the first and last at the ends**, are so placed as to be at equal distances apart on a 19-ft. lever. Where place the fulcrum for equilibrium?

9. Four hundred lb. are carried on a pole 16 feet long, supported on the shoulders of A and B. The weight is 2 ft. nearer A than B. What does each carry?

10. A beam 27 ft. long is supported at each end. At 8 ft. from one end is a weight of 800 lb. Four feet from the other end is a weight of 600 lb. What weight is carried by each support?

11. A lever of uniform size and density is 40 ft. long and weighs 400 lb. It is supported by two props, A and B; the former is 2 ft. from one end and the other is 6 ft. from the other end. What weight is carried by each?

12. In a lever of the third order 9 ft. long, with the lcrum at one end and 100 lb. weight at the other, where ace a power of 120 lb. for equilibrium?

13. What is gained by a lever of the third order? ustrate.

14. V. of P is to V. of W as 7 is to 1. The lever is ft. What are its arms?

15. A roll of butter weighs $1\frac{1}{2}$ lb. on one pan of a lse balance and 2 lb. on the other. What is the true eight?

CHAPTER II.

THE PULLEY.

Suspend a common pulley and over it pass a cord. To each end of the cord attach a brick. Observe that as pressure is applied to raise or lower either brick, equal lengths of the cord pass on and off the pulley. Hence, the

LAW OF THE PULLEY. The weight is as many times the power as the distance through which the power moves is times the distance through which the weight moves.

Flexibility of cord and friction are here disregarded.

A simple fixed pulley is a grooved wheel turning upon an axle. In its action it is a lever of the first order having equal arms. Hence no mechanical advantage can arise from its use. The fixed pulley changes the direction of the power.

EXPERIMENTS. 1. Arrange a fixed pulley so that a downward pull of the rope may raise a bucket of water.

2. Arrange two fixed pulleys so that a horse may raise by a horizontal pull on a rope a hod of mortar to the top of a building.

Show the above by actual arrangement and by drawing.

THE MOVABLE PULLEY. Pass a cord from a movable pulley bearing a weight to and over a fixed pulley as shown below:

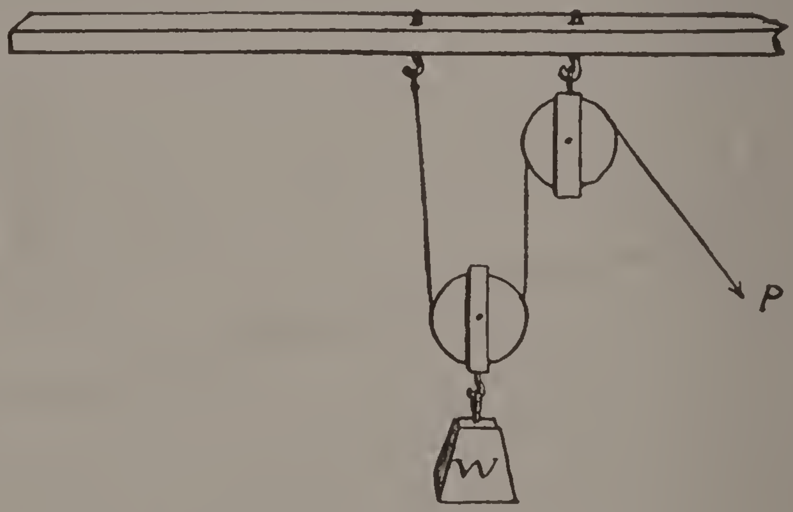


FIG. 8.

Determine the ratio between the distances through which the P and W move; also between the P and W.

From the work already done on the lever it will be seen that the movable pulley is a lever of the second order, the diameter of the pulley being the power-distance and its radius the weight-distance. Locate the fulcrum.

The size of all pulleys has direct reference to the flexibility of the cord.

It should be remembered that the efficient agent is the cord, and not the pulley, for excepting wear and friction a ring would do as well.

From the above it will be seen that a cord is a machine for transmitting force in any direction, while a lever can move a weight to or from the power only.

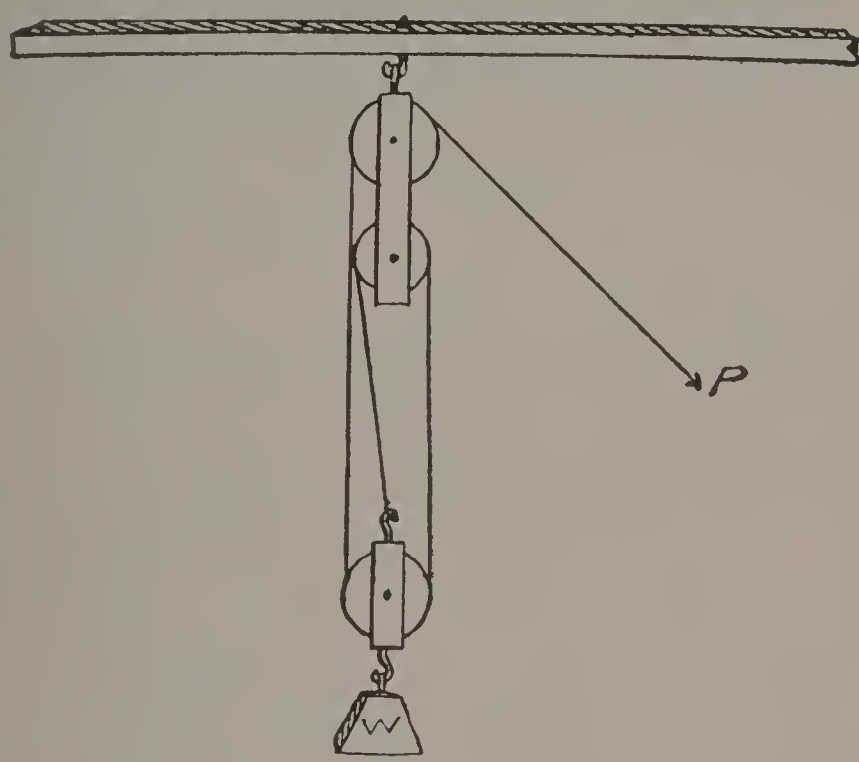


FIG. 9.

In the above diagram the movable pulley is supported by three parts of the cord, and, as the tension on each equals the power, the weight is three times the power.

In the former system the weight is supported by two parts of the cord; hence it is twice the power. In this system the weight is supported by three parts of the cord; hence it is treble the power.

In any system of pulleys having a continuous cord, the weight equals the sum of the tensions upon the parts of the

cord, and the number representing the parts of the cord is the ratio between the power and weight.

This ratio may be used in the solution of problems.

PROBLEM.

Thirteen lb. may be supported by what power with a continuous cord, one movable and two fixed pulleys.

There are three parts of the cord.

Weight is three times the power.

Power is $4\frac{1}{3}$ lb.

The power is 4 lb. with one movable and one fixed pulley. What is the weight?

The efficiency of any system having a continuous cord is increased by attaching the fixed end of the cord to the movable block. Why? Try it

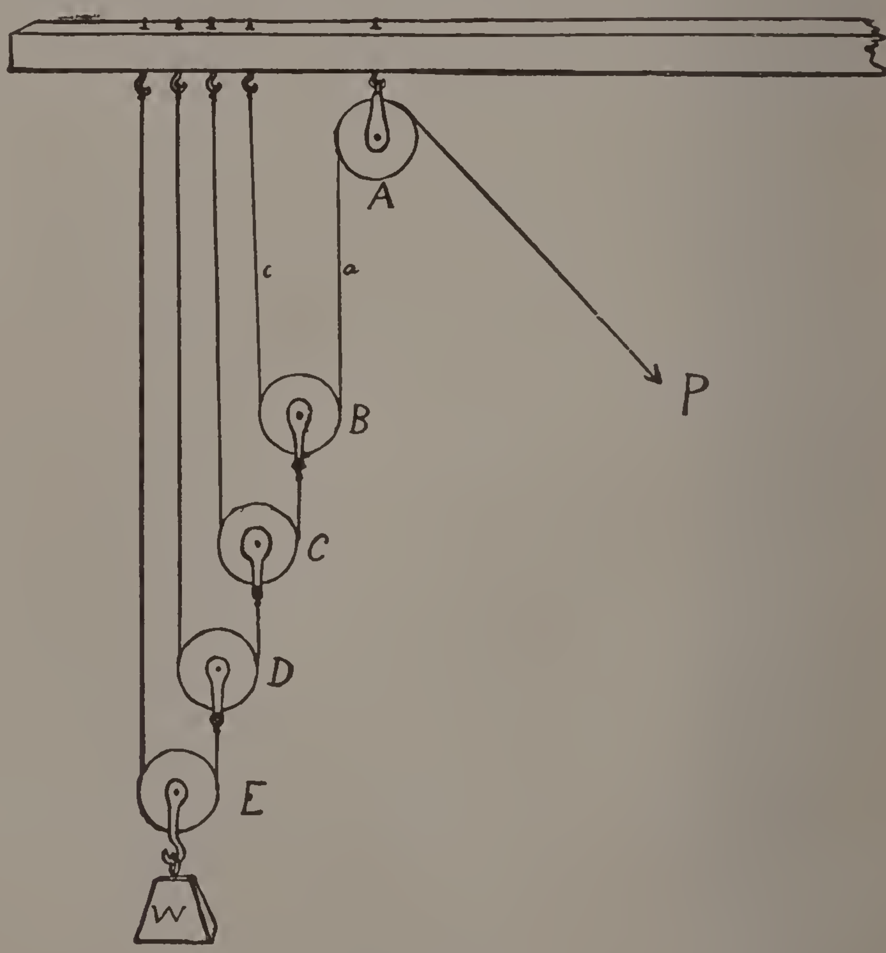


FIG. 10.

The system shown has four movable pulleys, each with a separate cord. The pulley A serves to change the direction of the power.

The tension on the hook at B is the sum of the tensions at A and C; hence twice the power. This system gives a great gain of power at the expense of range.

The value of such a system is in the doubling of the effect of the power at each successive movable pulley.

Raise 2 to the power indicated by the number of movable pulleys. This number is the ratio between power and weight and may be used to find either when the other is given.

Show by diagram a system of one fixed and three movable pulleys with separate cords.

PROBLEM.

In the above system what power will sustain a weight of 144 lb.?

Ratio between power and weight is 8.

Weight is 8 times the power.

Power is 18 lb.

Pulleys, however arranged, can give mechanical advantage by exchange only. These exchanges are limited to direction, velocity, distance, time and tension.

Show how a sewing machine exchanges intensity for velocity. Explain the exchange in the case of the windmill pump, the threshing machine, the coffee mill.

What pulley would you use for raising a bucket of water from a well? What system for raising a load to the top of a building with a horse? What system for pulling a safe up a stairway?

THE YALE PULLEY. This is a pulley manufactured by the Yale Lock Company. Its two points of excellence are:

1. The weight remains suspended at any point to which it has been hoisted.

2. A great ratio is obtained between the power and the weight.

This machine consists of a fixed pulley, having two grooves of unequal circumferences and a movable pulley, over both of which is passed an endless chain.

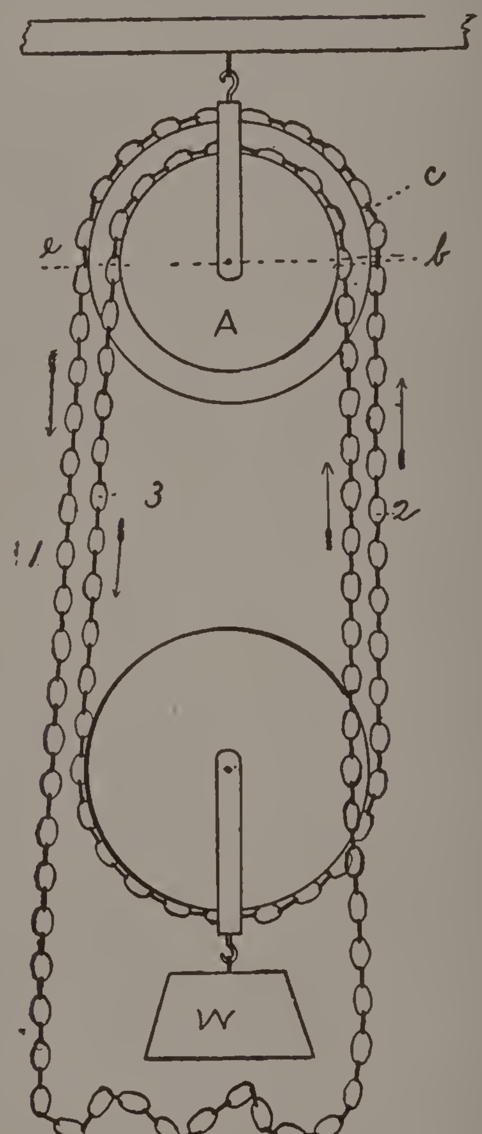


FIG. 11.

A is the single wheel with two grooves upon it.

The grooves are notched to receive the links of the chain.

Groove *b* is the circumference of a circle whose diameter is a little less than at *c*.

Suppose groove *b* to be 10 in., and groove *c* to be 12 in., from *b* to *c*.

Let the power at 1 be lowered 12 in. Chain 2 moves up 12 in., while chain 3 moves down 10 in., lifting the weight 1 in.

The ratio between the power and the weight is 12.

It is evident that this ratio may be increased by making less the difference between the length of the grooves upon the wheel A.

In most other pulleys the weight runs back when the power is removed.

Through the action of gravity, it is evident that the line of direction does not pass through the center of wheel A, but does pass midway between chains 2 and 3.

Since the chain cannot slip, the weight therefore remains suspended.

CHAPTER III.

THE WHEEL AND AXLE.

Attach one end of a cord to the axle of a grindstone and the other end to a weight. On turning the crank a large load may be easily lifted. The presence of the stone need not mislead the pupils.

The wheel and axle is a modified form of both lever and pulley. The lever appears in the unequal arms of the wheel and axle, and the pulley in its most efficient agent, the cord.

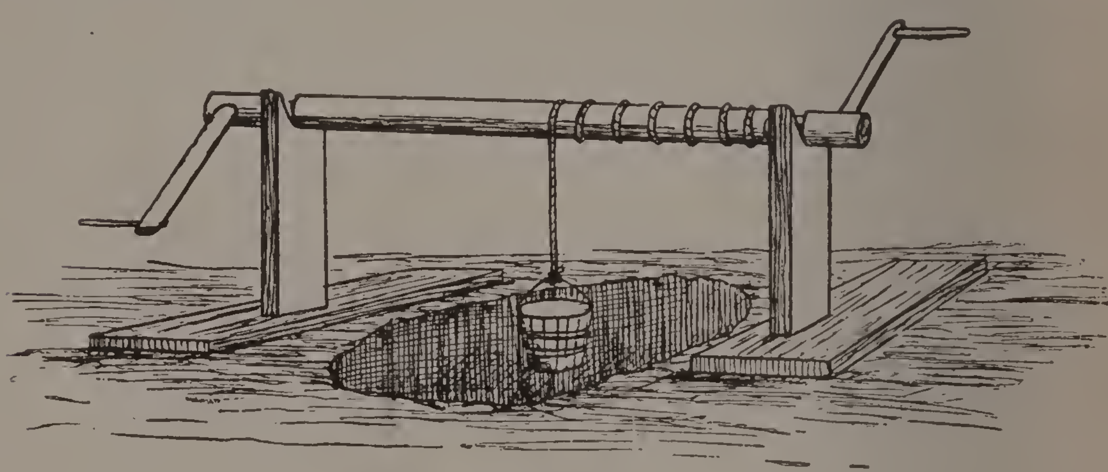


FIG. 12.

If the application of the power is at the circumference of the wheel or axle, there is a lever of the first order, the fulcrum being the common axis, and the arms being the radii of the wheel and axle respectively.

The wheel and axle is a machine of varying efficiency, due to the fact that whether the power is applied at the circumference of the wheel or axle, at two opposite points

in each revolution the order of lever changes. With the power applied at the circumference of the wheel, the levers are of the first and second orders; with the power applied at the circumference of the axle, the levers are of the first and third orders, as appears from the following diagrams:

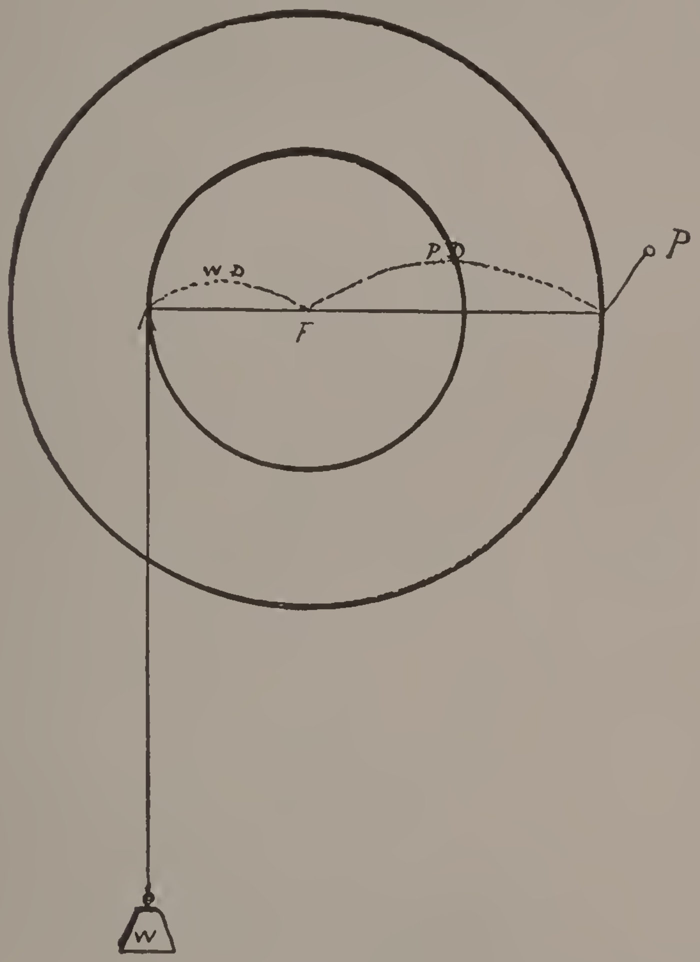


DIAGRAM A.

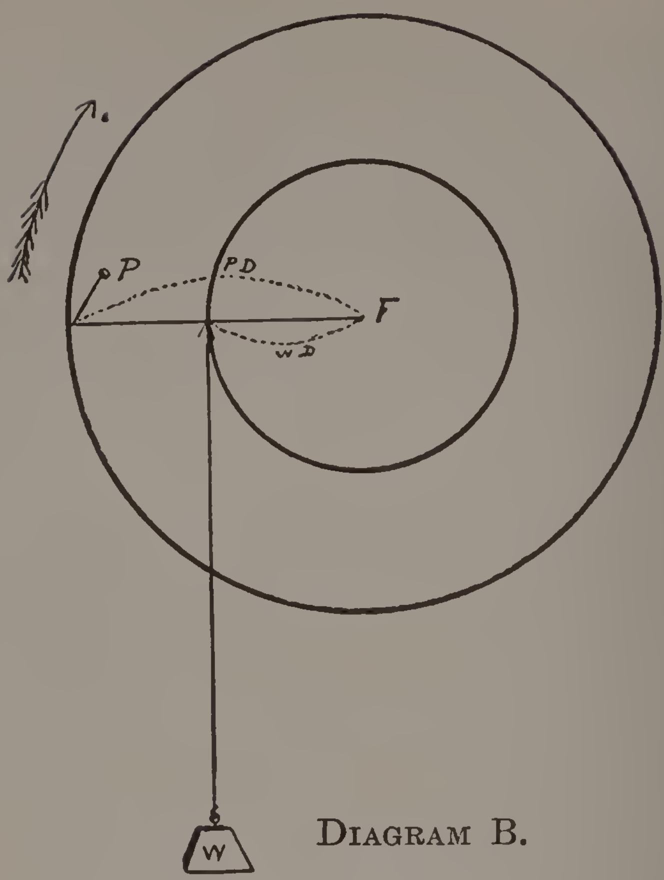


DIAGRAM B.

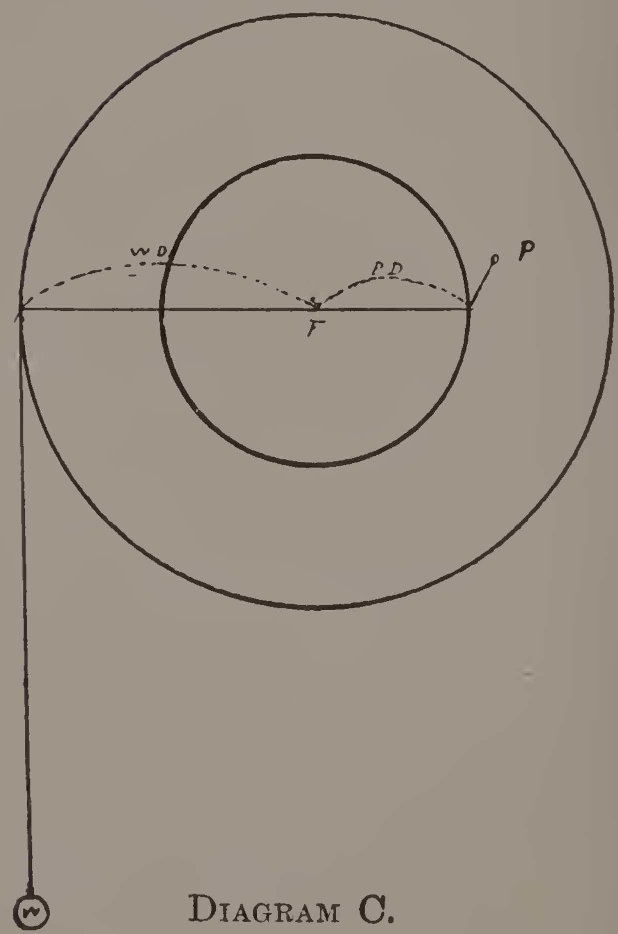


DIAGRAM C.

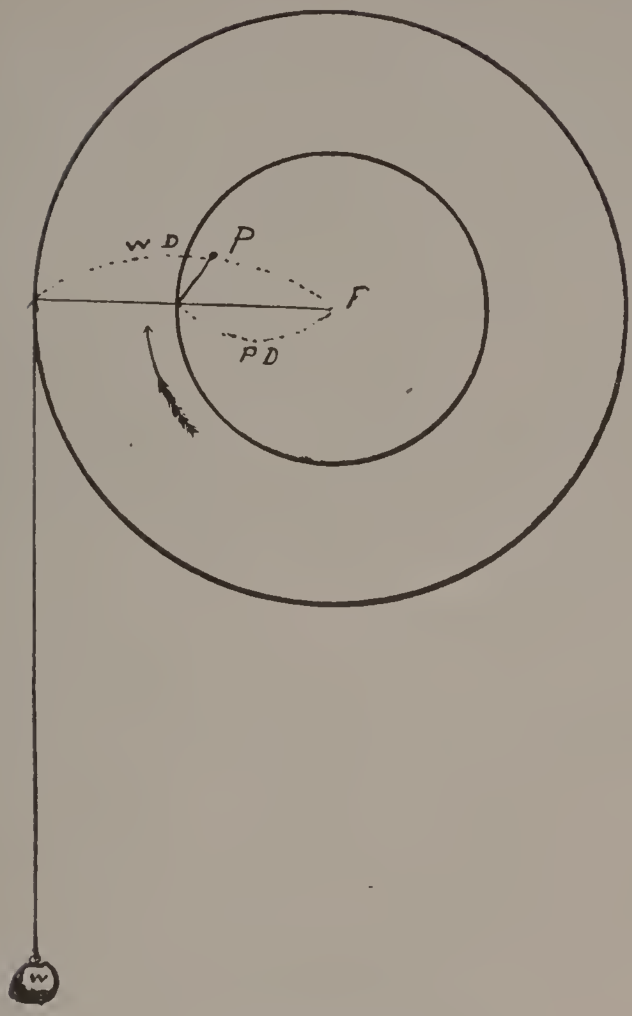


DIAGRAM D.

Inability to give uniform motion to a grindstone or windlass in use is seen from the above diagrams to be due to the change of levers at each revolution.

The law of the lever will apply to the wheel and axle when modified as follows:

In any two circles the ratio between their radii, diameters and circumferences is the same; therefore,

$$P : W :: \begin{cases} r : R \\ d : D \\ c : C \end{cases}$$

If the application of the power is at the circumference of the axle the proportions are,

$$P : W :: \begin{cases} R : r \\ D : d \\ C : c \end{cases}$$

The capstan is a wheel and axle in a vertical position and is used for moving heavy weights horizontally.

It is evident that the above laws apply equally as well to the capstan.

PROBLEM.

The diameters of a wheel and axle are respectively 36 and 4 inches. What power is required to support one ton?

The ratio between power and weight is 9.

Weight is 9 times the power.

Power is $222\frac{2}{9}$ lb.

The wheel and axle is a contrivance in which the lever and pulley appear in their greatest efficiency.

Describe and explain the uses of the following: Windlass, capstan, car-brake, pilot-wheel, derrick, wheel-tape.

CHAPTER IV.

THE INCLINED PLANE.

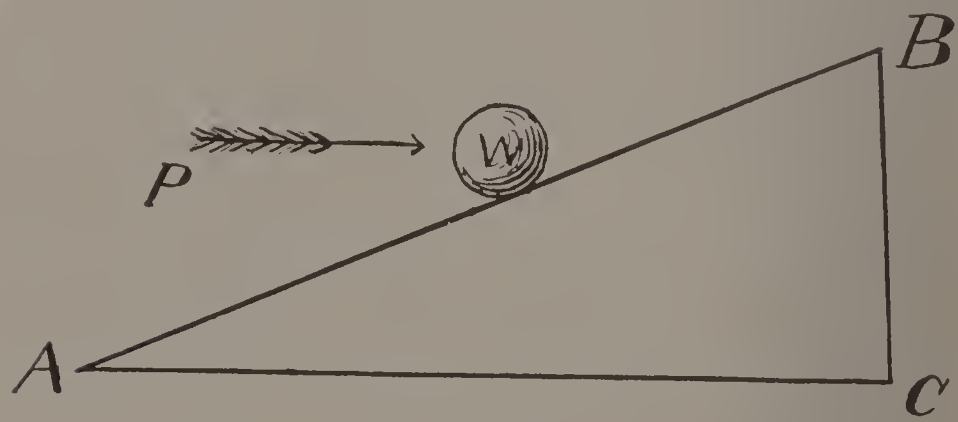


Fig. 14.

Observe that the top of the desk represents an inclined plane.

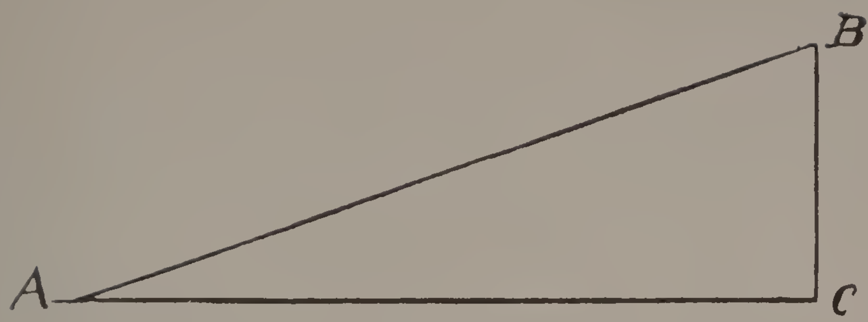


FIG. 13.

AB represents the length of the plane, BC the height, and AC the base.

The inclined plane is a smooth, unyielding, inclined surface.

Like the lever it is used in raising heavy weights.

The power may be applied in a direction parallel to the length of the plane, or parallel to its base.

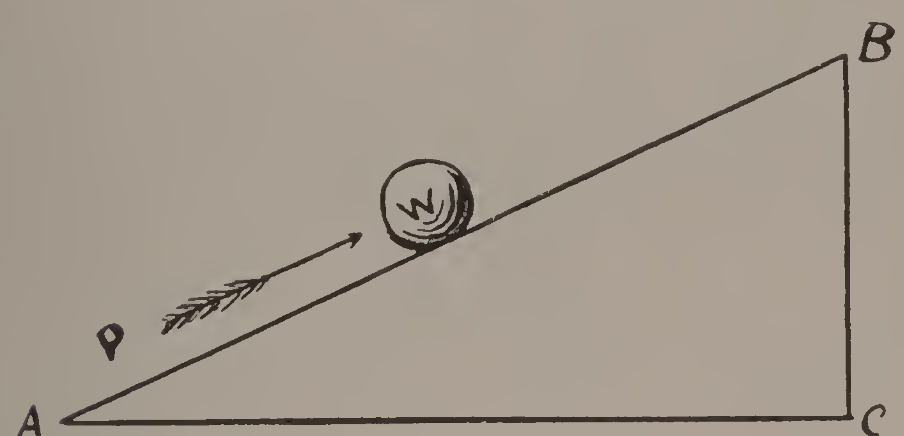


FIG. 14.

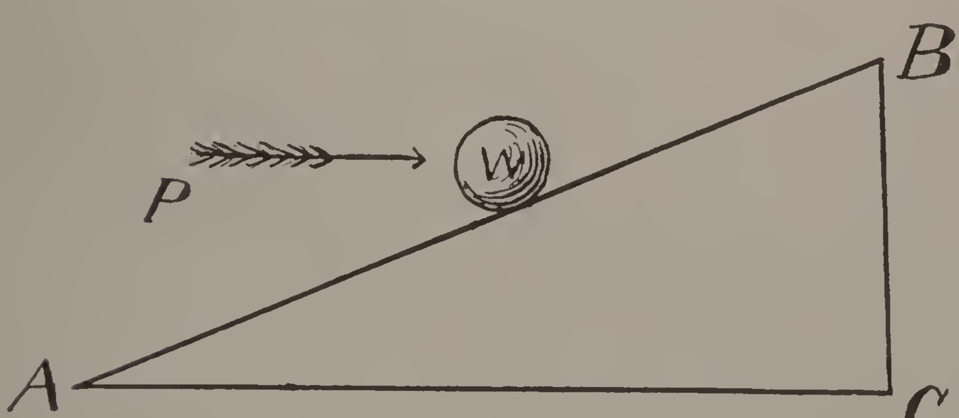


FIG. 15.

In either case the height of the plane is the weight-distance.

The power-distance is either the length of the plane or the length of its base.

When the power acts in a direction parallel to the length of the plane, the ratio between its length and height is the ratio between the power and the weight.

PROBLEM.

What power is required to raise a barrel of flour into a wagon 4 ft. high on a ladder 12 ft. long?

Let the power be applied in a direction parallel to the length of the plane.

The ratio between the power and the weight is 3.

The weight is 3 times the power.

The power is 65⅓ lb.

When the power acts in a direction parallel to the base of the plane, the ratio between its base and height is the ratio between the power and weight.

PROBLEM.

The base and height of an inclined plane are 20 ft. and 2 ft. respectively. What power acting in a direction parallel to its base will be required to support a ton?

The ratio between the power and weight is 10.

The weight is 10 times the power.

The power is 200 lb.

The demonstration of these statements may be found in special text-books.

The inclined plane has its greatest practical value in the skid, bridge, and viaduct.

The chute is employed in moving logs down mountain

sides to the mill below, and again for raising them from the water to the saws.

The greater the difference between the length and height of the plane, the less the power, the weight being the same.

The **highest utility** of the inclined plane appears in flumes, water courses, pitch of roofs and gradients. The school boy knows the value of the incline from the use of roller skates and the express wagon.

A street grade of 1 in 20 means that for every 20 ft. of advance there is a rise of 1 ft.

A carriage on a smooth road will yield to gravity and descend when the grade is more than 1 in 20, but a railway car will do the same when the grade is 1 in 150. Why?

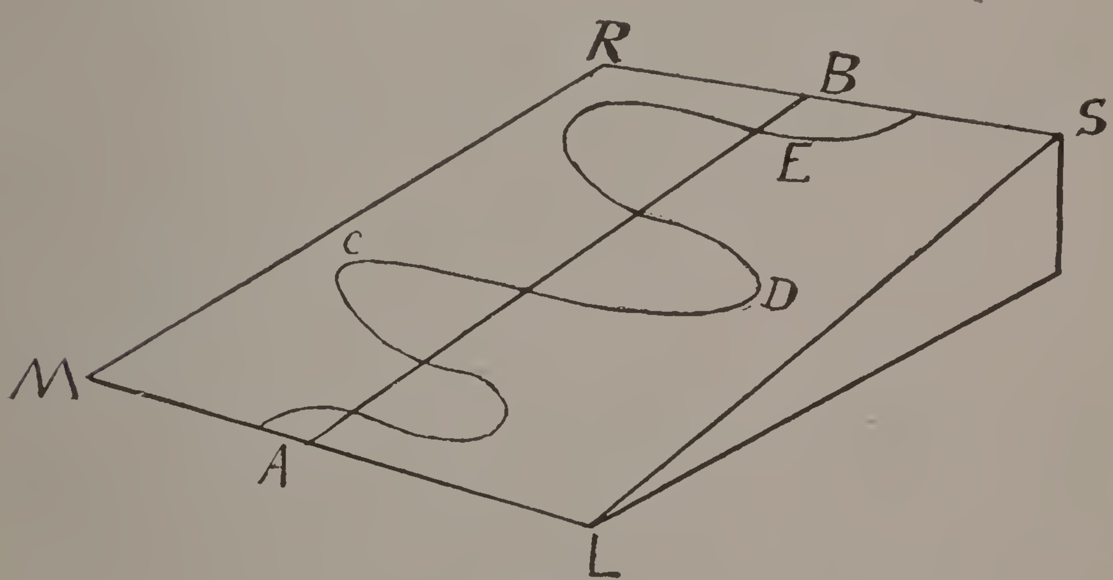


FIG. 16.

Let MLRS represent a street grade of 1 in 5. A horse with an inexperienced driver will be urged up the incline in the direction of the line AB. If left to himself he will take the zigzag course shown by the line CDE. Why?

Engineers may have seen this act, for it is by length-

ening the plane by winding that railroads cross mountains. Nature thus indicates the direction of commercial routes by her water courses.

Whenever the incline is so great that the force of gravity exceeds traction the grade is impracticable.

CHAPTER V.

THE WEDGE.

Instead of moving a load on an inclined plane we may thrust an inclined plane under the load. From this it appears that the wedge is a movable inclined plane. Its use is to separate two surfaces that are pressed or drawn together. For such purpose the wedge is usually double.

Examine the blade of a pocket knife. What kind of a wedge is it?

With it make three wedges and illustrate the following:

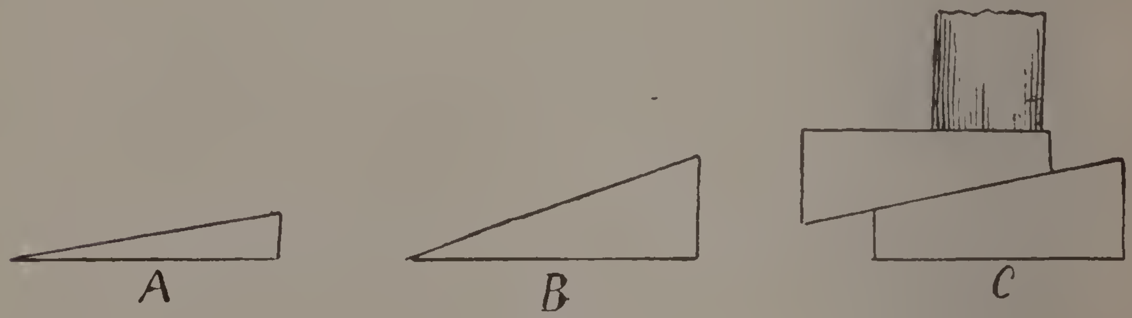


FIG. 17.

The simplicity and effectiveness of the wedge, whether single or double, makes it of great value. It appears in the edged tools of the mechanic and artisan. It is seen in the keystone of the arch of the mason, as well as in the plow and ax of the farmer.

Name a dozen tools illustrating the wedge.

The wedge works on the principle stated in the second

case of the inclined plane. The length of the wedge represents the base of the plane and its thickness, if single, the height of the plane.

The wedge is moved by percussion. It is made to overcome the resistance by the friction of its surfaces. If it is too smooth or is oiled it is valueless.

Since the ratio of a blow to a resistance cannot be easily estimated, the theory of the wedge has no practical value. Hence no problems on the wedge are given.

As a machine the wedge is especially useful when it is required to exert a great force through a small space. Ships are raised in docks by wedges driven under their keels, and are launched by their removal.

Wedges are used to straighten chimneys, to cleave timber, and press the oil from seeds.

In the application of the principle of the wedge to tools, the strength of the tool is diminished as the angle is lessened. Approximately, the angle is 30° for cutting wood, 60° for iron, and 90° for brass.

CHAPTER VI.

THE SCREW.

Examine a common screw and name its parts. How many times must the screw in hand be turned around to advance its length? The head of the screw has a crease by which it is turned. The threads upon it are inclined planes by which it is forced in or out.

Cut from paper a right-angled triangle whose hypotenuse is but little more than its base, and wind this triangle upon a pencil with its base at right angles to it, thus:

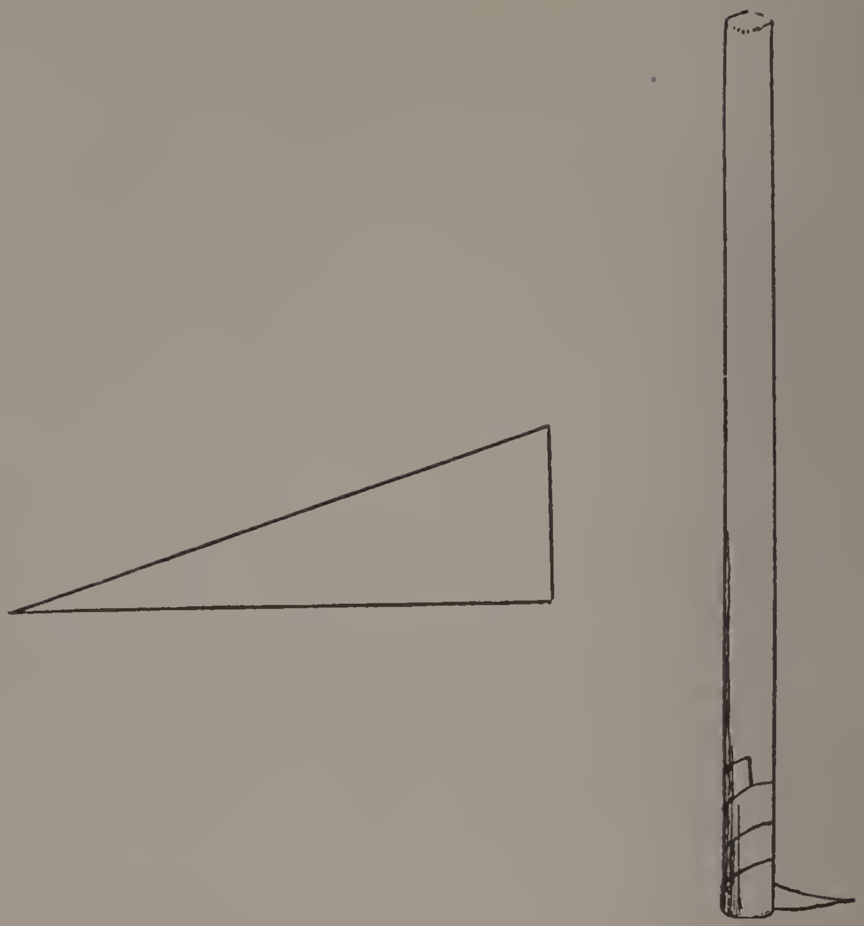


FIG. 18.

Notice that the exposed edges of the paper represent the threads of the screw, and the distance between them its pitch.

The screw is a spiral inclined plane. It exchanges velocity for intensity and at a great rate. It is, therefore, among the most powerful of mechanical appliances.

The nut is a short hollow cylinder whose inside thread fits into the spaces between the threads of the screw.

Either the nut or the screw may be stationary.

In problems upon the screw, beside power and weight, regard is had for two things only,—the distance through which the weight moves and the distance through which the power moves.

While the weight moves through a distance equal to

the pitch of the screw, the power moves through a distance equal to the circumference of the circle which it describes.

The ratio between the circumference of the circle which the power describes and the pitch of the screw is the ratio between the power and the weight.

PROBLEM.

What weight may be raised by a screw whose pitch is $\frac{1}{8}$ in., and the lever in the head of the screw 5 ft. long, the power of 20 lb. being applied at the end of the lever?

The ratio between the power and the weight is $2 \times 5 \times 3.1416 \times 12 \times 8$, which is 3015.936.

The power is 20 lb.

The weight is 3015.936×20 lb., which is 60318.72 lb., or 30.1036 tons.

The common illustrations of the screw are: Carriage bolts, carriage screws, lag screws, interior of rifled guns, gimlets, bits, augurs, screw propellers, copy and cider presses, and jack screws of all forms.

In concluding these simple and brief statements upon the mechanical powers, the suggestion is offered that the careful teacher will lead his pupils to the fullest illustration and explanation of as many of the common appliances of life as possible.

Some one or more of the mechanical powers will be found to appear in the simplest of tools, and it should be the aim of the teacher to see that **observation** is followed by **interpretation** and careful application.

It is not too much to say that man has copied all the mechanical powers from nature. The lever appears in all animal movements. Infusoria, the rotifer and paramoecium illustrate the wheel. The principle of the cord and

pulley is seen in the use of tendons, especially in the eye. Teeth, tusks, horns, hoofs, beaks, and claws show the origin of the inclined plane and wedge.

Nature presents two kinds of screws, the right and left, as seen in the bean and the hop.

Convenience dictates the right handed screw, owing to the custom of men. From the structure of the plant to the huge weapon of the narwhal, the screw appears not so much as a mechanical power as a form of tissue combining strength and beauty. Whirlwinds and water spouts, which work on the principle of the screw, are nature's greatest illustrations of her efforts in producing an equilibrium of forces.

MISCELLANEOUS PROBLEMS.

1. A horse attached to the end of a 12 ft. lever of a capstan pulls 300 lb. The axle of the capstan has a radius of 6 in. What weight can be moved?

2. With 5 movable pulleys and separate cords, what power will be required to support 160 lb.?

3. With a continuous cord, one fixed and two movable pulleys, what will a pull of 6 lb. support?

4. The base of an inclined plane is 14 ft. Its height is 2 ft. What power acting parallel to the base will support 90 lb.?

5. What weight can be held on an inclined plane 10 ft. long and 2 ft. high with 80 lb. of power? (Two cases.)

6. A screw has 4 threads to the inch. A weight of 6,000 lb. is to be raised. How long a lever is necessary with a power of 100 lb.?

7. From the palm of the hand to the elbow is 12 in.; from the elbow to the point of attachment of the muscle is 2 in. What muscular strain is necessary to raise a 10-lb. ball in the hand?

8. An inspector finds a parcel on a grocer's balance weighing 5 lb. on one pan and 4 oz. less on the other. What is the true weight?

9. The scale beam of a certain steelyard is 30 in. from the bearing nearest its center. The distance between the bearings is $\frac{3}{4}$ in. What weight at the end of the beam will balance a load of 50 lb.?

10. One arm of a teeter-board is twice as long as the other, the board being 12 ft. long. A boy weighing 45 lb. sits at the end of the longer arm. Where must a boy weighing 120 lb. sit so that the two will be in equipoise?

As in the preceding pages, treat the following topics, of which limited space forbids more than a mere outline.

The following syllabi are intended as aids in the assignment of lessons by topics, to be studied from any text-book.

In assigning lessons, the following points may be found helpful:

1. The topic.
2. The topic chosen should be a unit in itself.
3. Cautions as to use of text-book, regarding what to study and what to omit.
4. An opportune time for the assignment of the lesson is at the beginning of the recitation.
5. See that the topics are related.

CHAPTER VII.

MATTER AND ITS PROPERTIES.

The following figures indicate Laboratory work. Each cut is intended to show how one or more of the properties

of matter may be clearly comprehended, leaving the pupil to decide what that property is and how he found it out.

Pupils are expected to reproduce the drawings.

Snap a card from under a marble over a bottle.

Fig. 19.

Swinging balls.

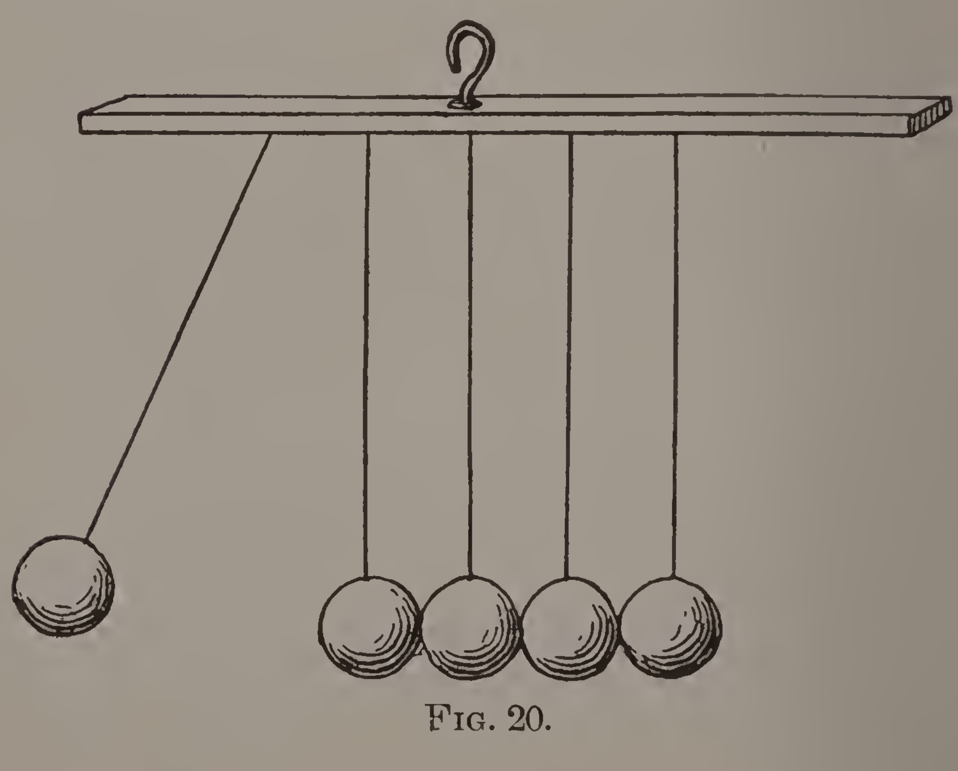


Fig. 20.

Shoot a candle through a board.

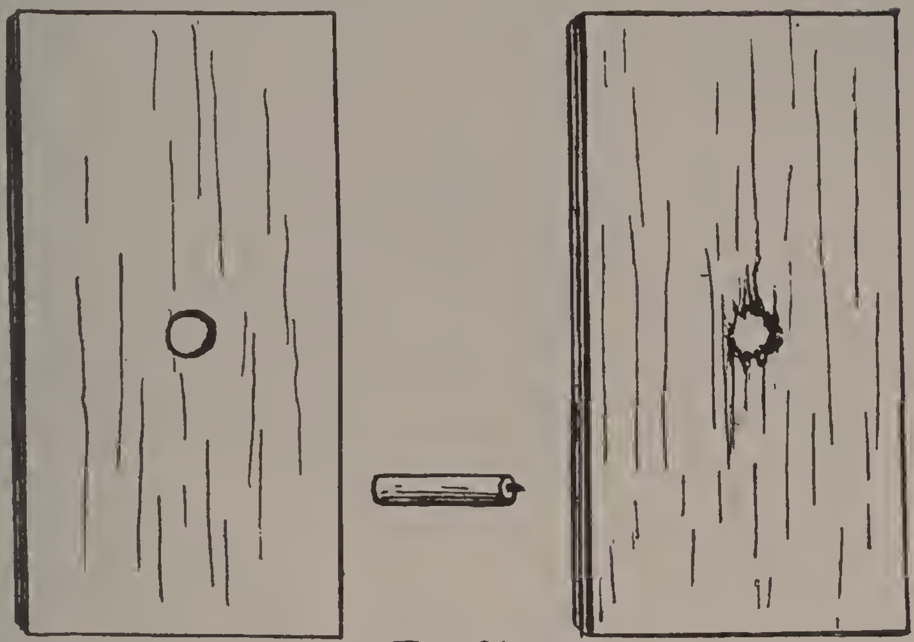


Fig. 21.

Put nails into a glass full of water.

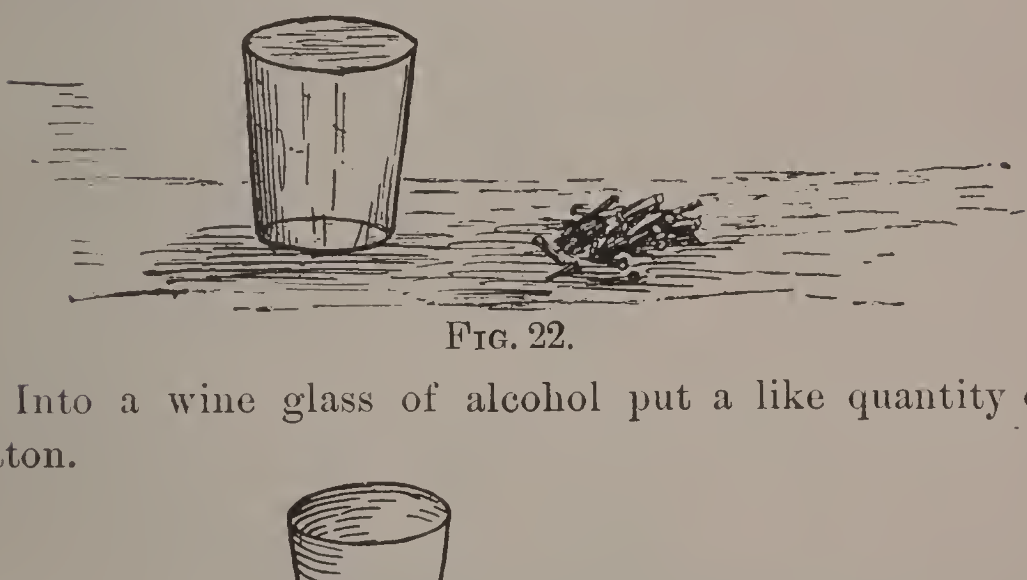


Fig. 22.

Into a wine glass of alcohol put a like quantity of cotton.

Fig. 23.

Invert a goblet in water.

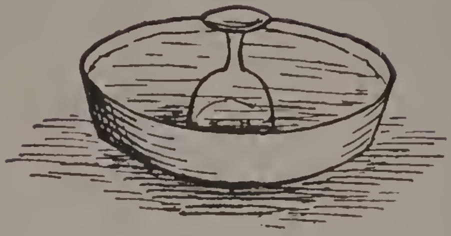


FIG. 24.

Pour water into a funnel inserted air tight into a bottle.

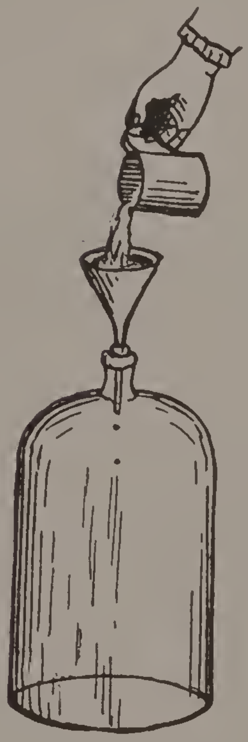


FIG. 25.

Push a cork into a bottle and remove it.

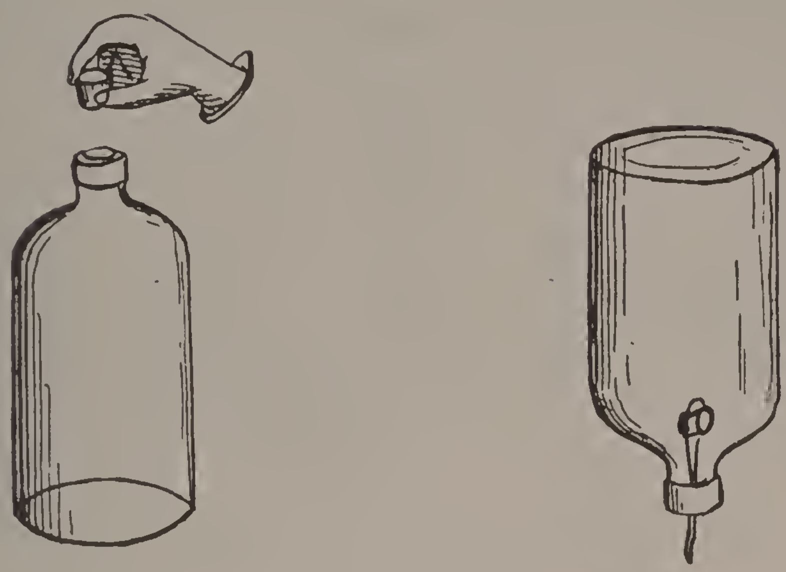


Fig. 26.

Drop an inked ivory ball on marble.

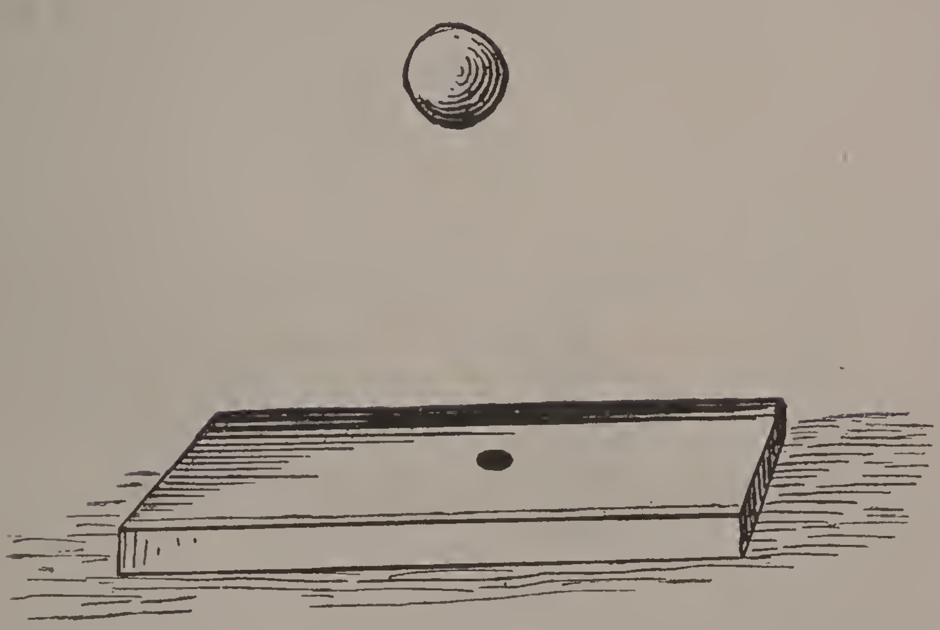


Fig. 27.

Vortex rings. (Put hydrochloric acid and ammonia in separate dishes in the box.)

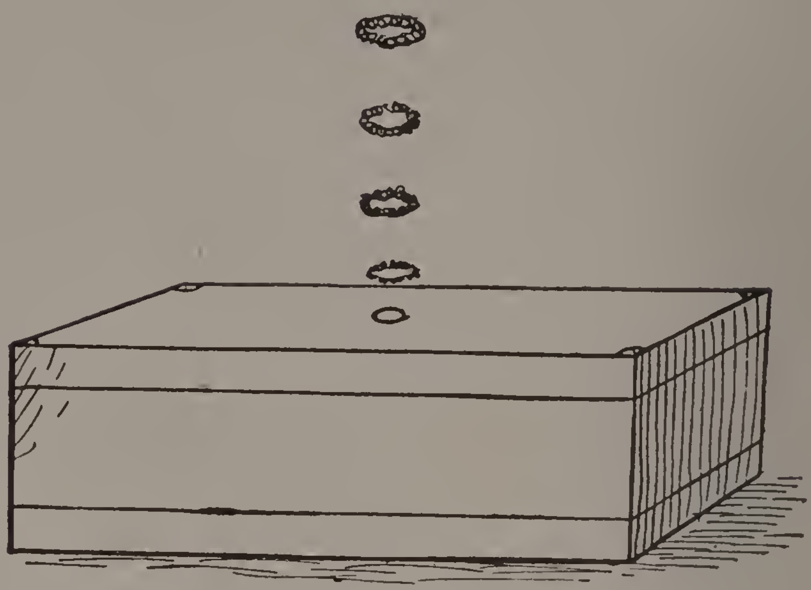


FIG. 28.

Draw a wire back and forth around a cylindrical stick and then measure.

FIG. 29.

Cut a bottle.

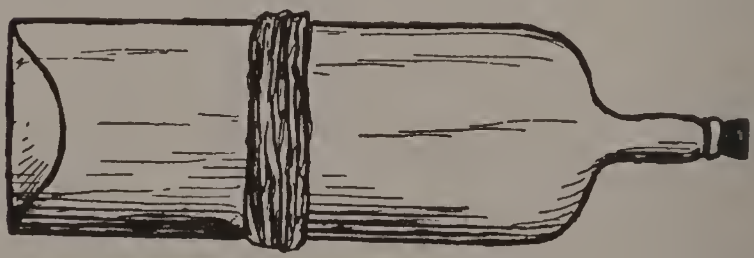


FIG. 30.

DIRECTIONS. Confine the air in the bottle to be cut. Wrap yarn soaked in kerosene around the bottle near the

desired cut. Secure the ends of the yarn without a knot. Light the soaked yarn and hold the bottle horizontally and rotate. If there is yarn enough the bottle will break without using water.

If the bottle is thick a light scratch is favorable to the experiment.

Show the mercury shower.

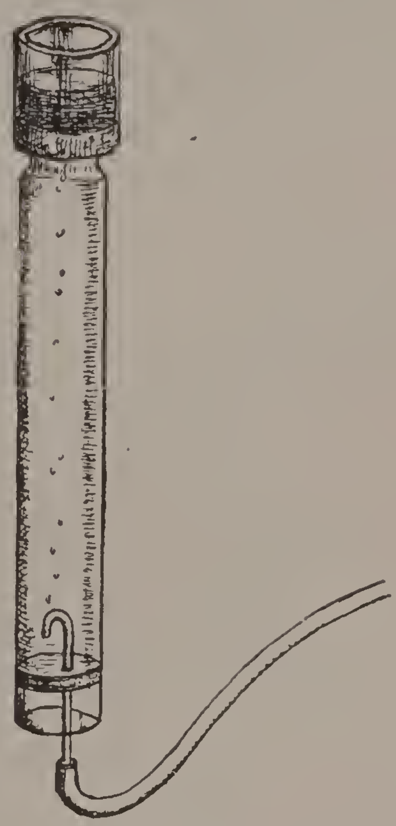


Fig. 31.

COHESION AND ADHESION. Cohesion is the force that aggregates molecules and resists their separation.

Adhesion and capillarity are forms of cohesion.

To which do the following belong? Give reasons.

Write upon the blackboard with crayon.

Open a sealed envelope without cutting or tearing it.

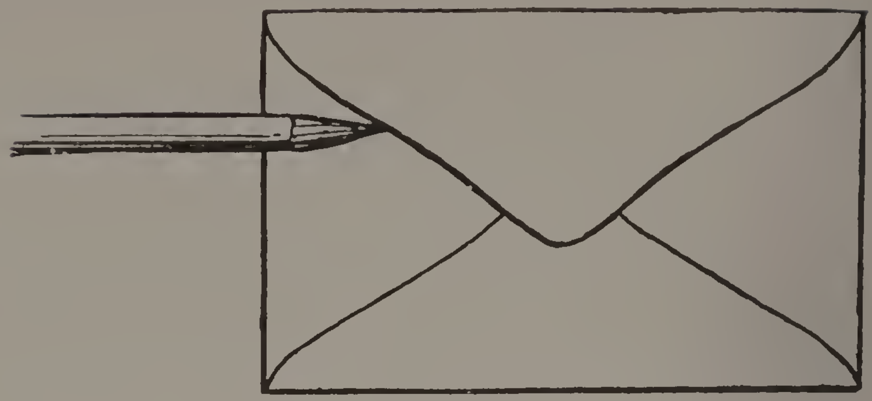


FIG. 32.

Cut a rubber eraser with a dry blade. Try a wet blade.

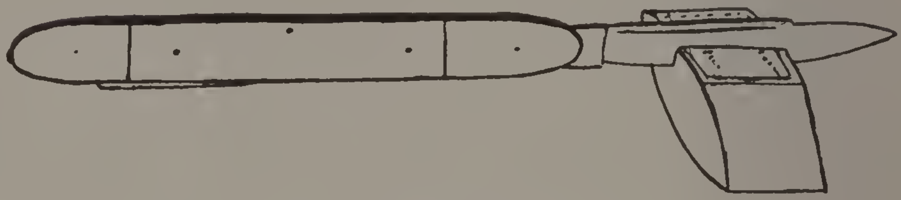


FIG. 33.

CHAPTER VIII.

PHYSICAL AND CHEMICAL CHANGES.

A physical change is a change in which the molecule is not decomposed.

A chemical change is a change in which the molecule is decomposed.

THE MOLECULE AND THE ATOM. A molecule is the smallest particle of matter that can be produced by physical means and can exist alone.

An atom is the smallest particle of matter that can be produced by chemical means and cannot exist alone.

Perform the following experiments. Classify the changes and fully explain them.

Blow through lime water.

FIG. 34.

Let a silver spoon stand in whipped egg.

FIG. 35.

Make a ball of Plaster of Paris.

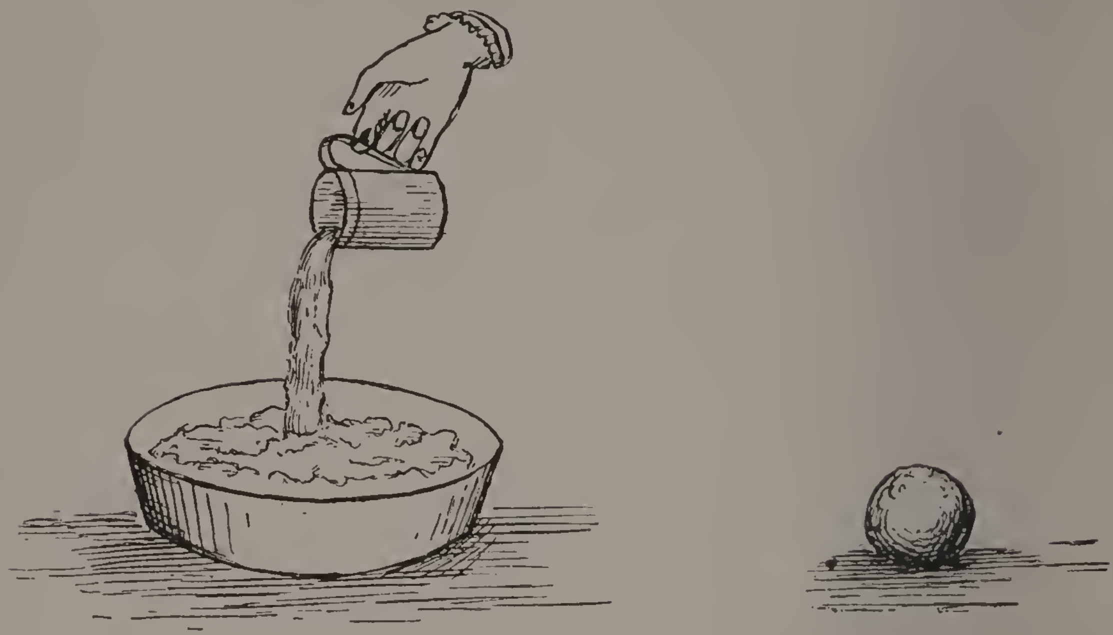


FIG. 36.

Pour water on baking powder.

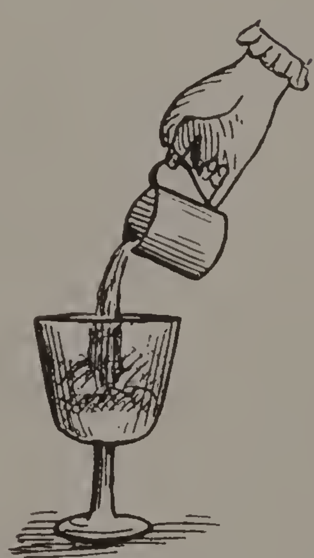


FIG. 37.

Pour into a test-tube half full of water, one-third as much alcohol. Test for temperature.

FIG. 38.

State and classify the changes in baking potatoes, making vinegar, bread, biscuit, butter.

CHAPTER IX.

MOTION.

Motion is the change of position in any atom, molecule, or mass of matter.

The molecules of a pebble are, at no two successive instants of time, in the same position respecting each other. If the pebble be thrown into the air, it occupies

different positions in space from point to point in time. The earth in its revolution around the sun and a moving train on a track have at no two successive points of time the same positions in space.

Discuss:

Motion.
(a) Kinds.
(b) Laws.
(c) Momentum.
(d) Give illustrations.

POWER.

Power is that which itself begins, increases, or retards motion in any atom, molecule, or mass of matter.

A rifle ball is hurled through space; a glacier or an avalanche slides down a mountain side; a planet is held in its course about the sun. These are manifestations of power.

Power is a generic term—the most comprehensive used in dynamics. It includes force and energy. (See "Force and Energy," by Grant Allen.)

FORCE.

Force is a power which aggregates atoms, molecules, or masses of matter.

Oxygen and hydrogen atoms unite to form molecules, and these to form masses of water; a boulder crashes down a mountain side; a river rolls onward to the ocean. These are manifestations of force.

Discuss:

Force.
1. Kinds.
(a) Chemical affinity.

(b) Molecular attraction.
(c) Gravity.
(d) Electrical attraction.

2. Units.
3. Result or work.

Chemical Affinity is the force that unites atoms into molecules.

Molecular Attraction is the attraction between molecules —whether alike or unlike.

Gravity is the attraction between masses of matter.

Electrical Attraction. This manifestation of force has been given the above place because of its increasing service to man.

It, like electricity, is difficult to define. It may not be amiss to say that **Electrical Attraction is the force existing between unequally electrified bodies.**

CHAPTER X.

GRAVITY.

Under this term are considered Falling Bodies and the Pendulum.

FALLING BODIES. From the accompanying diagram deduce the following formulæ, if

g = effect of gravity or $32\frac{1}{6}$ ft.,
t = time,
v = velocity,
d = distance for any second,
s = sum of distances.

FORMULÆ.

1. $v = gt$
2. $d = \frac{1}{2}g(2t-1)$
3. $t = \frac{1}{2g}(2d+g)$
4. $s = \frac{1}{2}gt^2$

The formula for d when representing a half second is derived from,

$$s = \tfrac{1}{2}gt^2$$

Substituting, $s = 16\tfrac{1}{12} \times \tfrac{1}{4}$

Hence, $d = 4\tfrac{1}{48}$ ft.

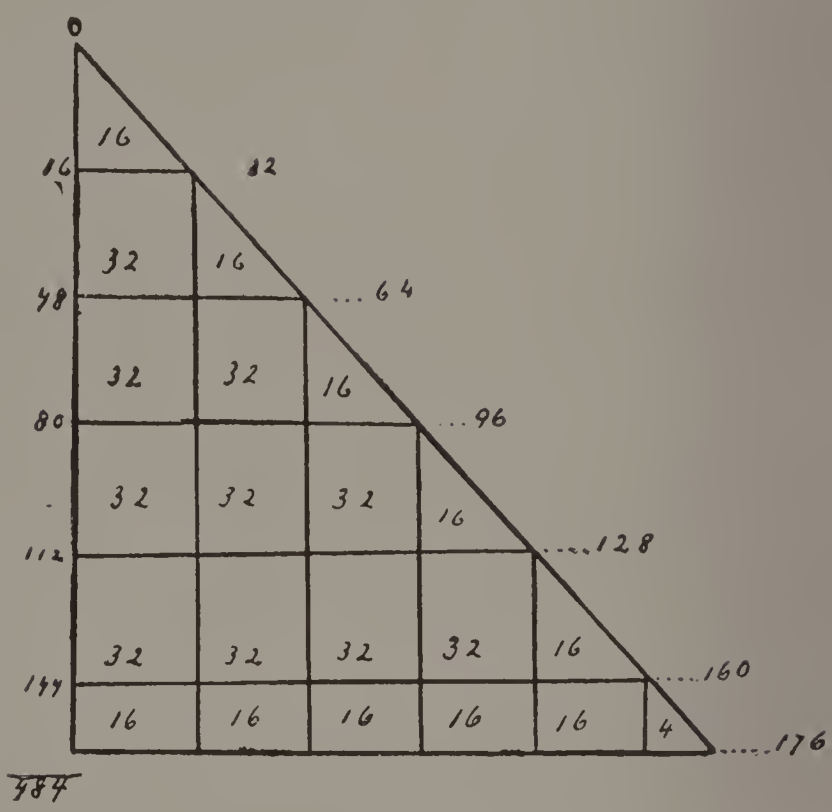


FIG. 39.

PENDULUM. Topics: Kinds, Motions, Real Length, Oscillations, Center of Oscillation, Vibration, Time of Vibration, Amplitude of Vibration, Laws, Formulæ. Give problems.

MISCELLANEOUS PROBLEMS.

1. 100 lb. at the surface of the earth will weigh how much 50 miles below the surface?
2. How far will a body fall during the third second?
3. How long will it take a body to fall 100 ft.?
4. Through what distance will a body fall in $7\tfrac{1}{2}$ seconds?
5. How long will it take a body to fall 579 ft.?

6. A body is thrown vertically upward 100 ft. How many seconds will elapse from its leaving the earth to its return?

7. How long is a pendulum which beats once in two seconds?

8. How often will a pendulum beat that is 4.35 in. long?

9. What is the final velocity of a falling body at the end of the seventh second?

10. A body falls 700 ft. in 6 seconds. What was its initial velocity?

CHAPTER XI.

ENERGY.

Energy is a power which separates atoms, molecules, or masses of matter.

The energy of heat separates particles of matter in explosions. Muscular energy may be stored up in a suspended ball, which expends it on being separated from the point of support.

The heat energy of the sun stored up in coal may be transmitted to water, then to steam, and afterward appear in the working engine, the rotating spindle, and the moving fabric.

MODES OF ENERGY. (a) Potential.
(b) Kinetic.

Potential energy is the statical separation of portions of matter.

A hanging lamp, confined steam, a stone on a mountain top are illustrations.

Kinetic energy is the energy of motion, as the flying of a bird or the spinning of a top.

These modes of energy are interchangeable. Show it.

CHAPTER XII.

PNEUMATICS.

This division of Physics affords ample scope for original experimentation.

It has been found a profitable exercise for students to come before the class and perform and explain experiments as a teacher would do. The presence of the teacher, the questions of the class, and the natural pride of the student are all powerful stimuli for developing the best efforts of the experimenter.

It is presumed that, in such a course, the experiments have been previously assigned to individuals or to the class as a whole.

The following figures illustrate easy experiments that may be profitable when performed, represented, and explained.

Perform the barometer experiment.

Fig. 40.

Same experiment after lifting the tube of mercury from the bowl.

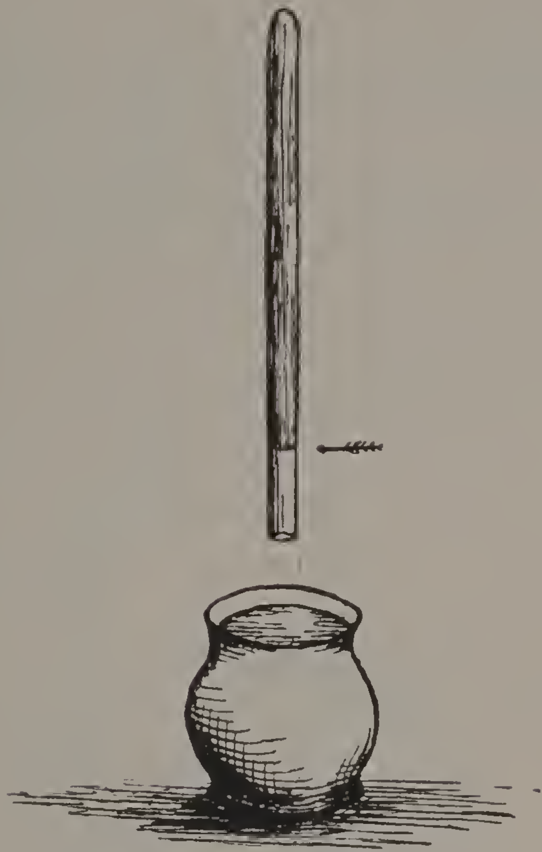


Fig. 41.

Same experiment with the tube in an oblique position.

Fig. 42.

Perform the same experiment as shown in the cut below.

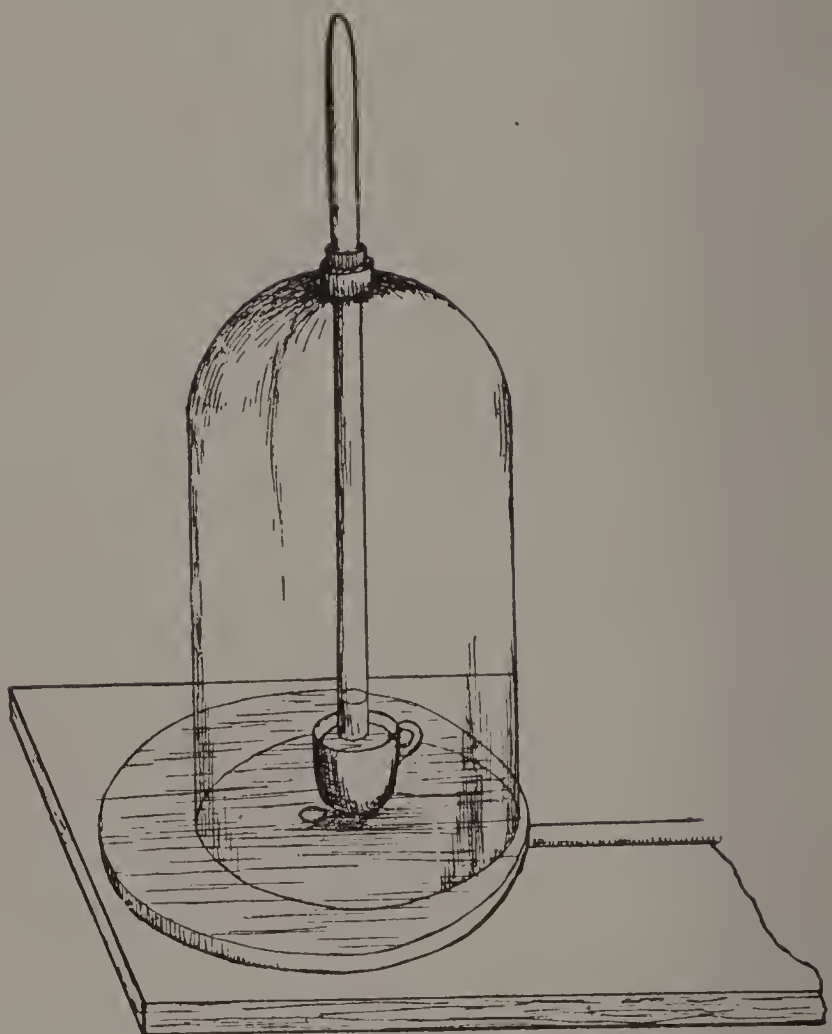


Fig. 43.

THE CHAPMAN ASPIRATOR. This instrument may be understood from the drawing.

Its chief use is in rapid filtering and in exhausting air by means of flowing water. A head of 30 ft. gives good results.

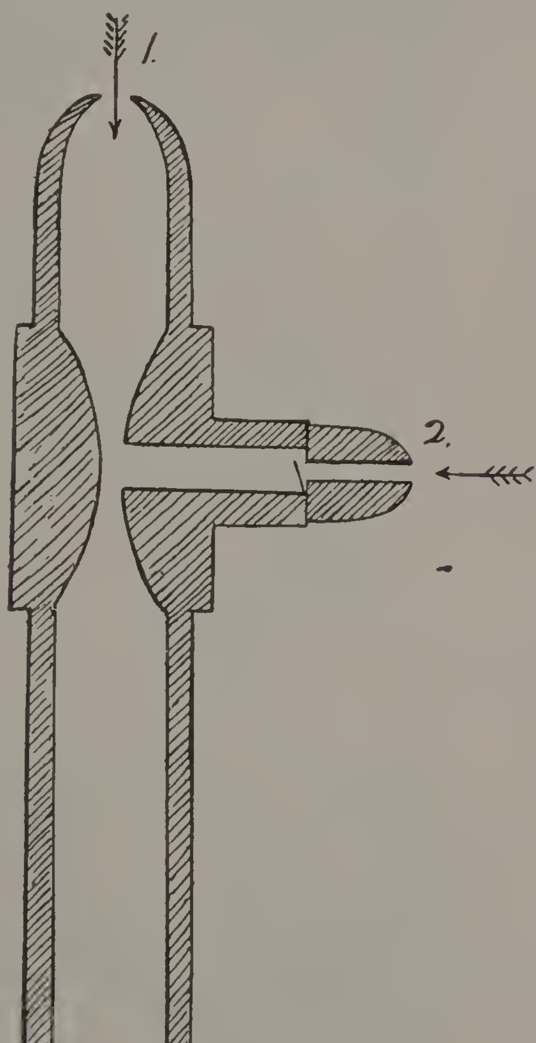


FIG. 44.

The sucker.

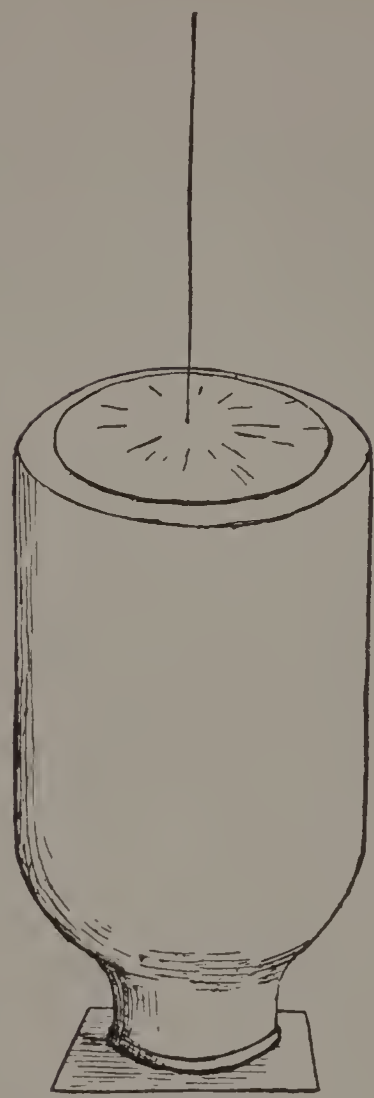


Fig. 45.

Place a brick flatwise in a dish filled with water.

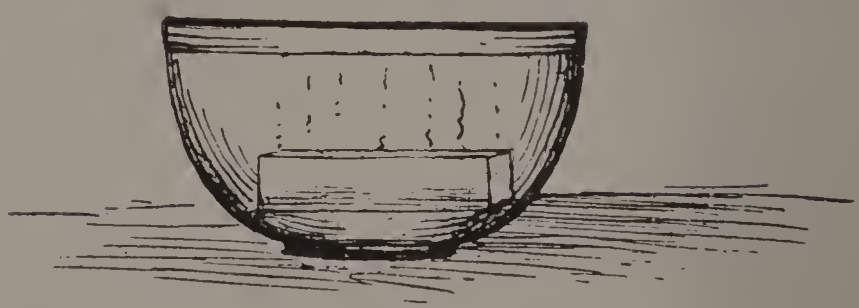


Fig. 46.

Apply the palm of the hand to a piece of paper placed upon a goblet full of water. Invert the goblet and remove the hand.

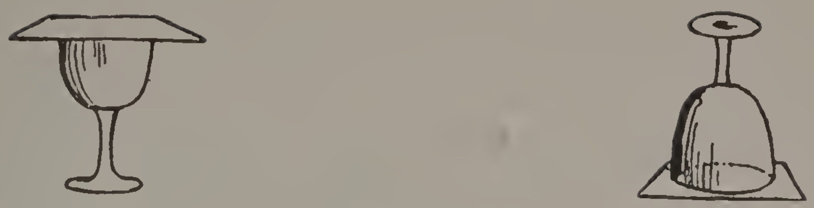


Fig. 47.

Drink through a straw from a glass of water.

Fig. 48.

Burn a piece of paper in a goblet inverted over water.

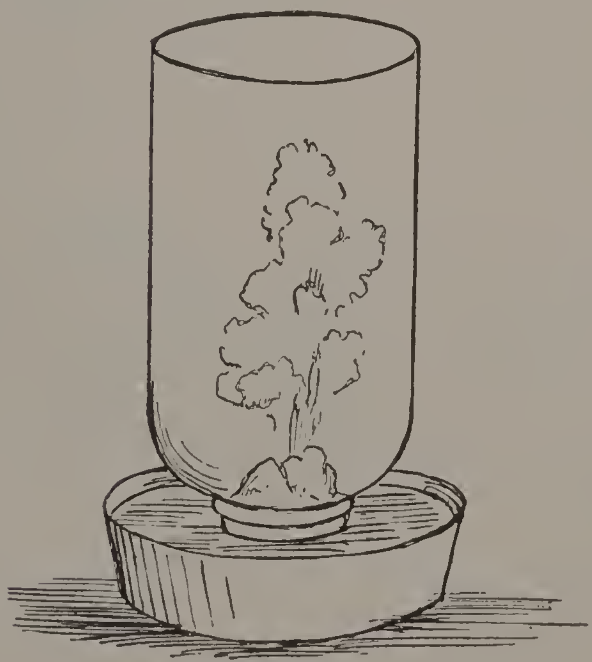


Fig. 49.

Fill the larger jar with water. Cover with water the sliced potatoes in the smaller jar. Exhaust the tube.

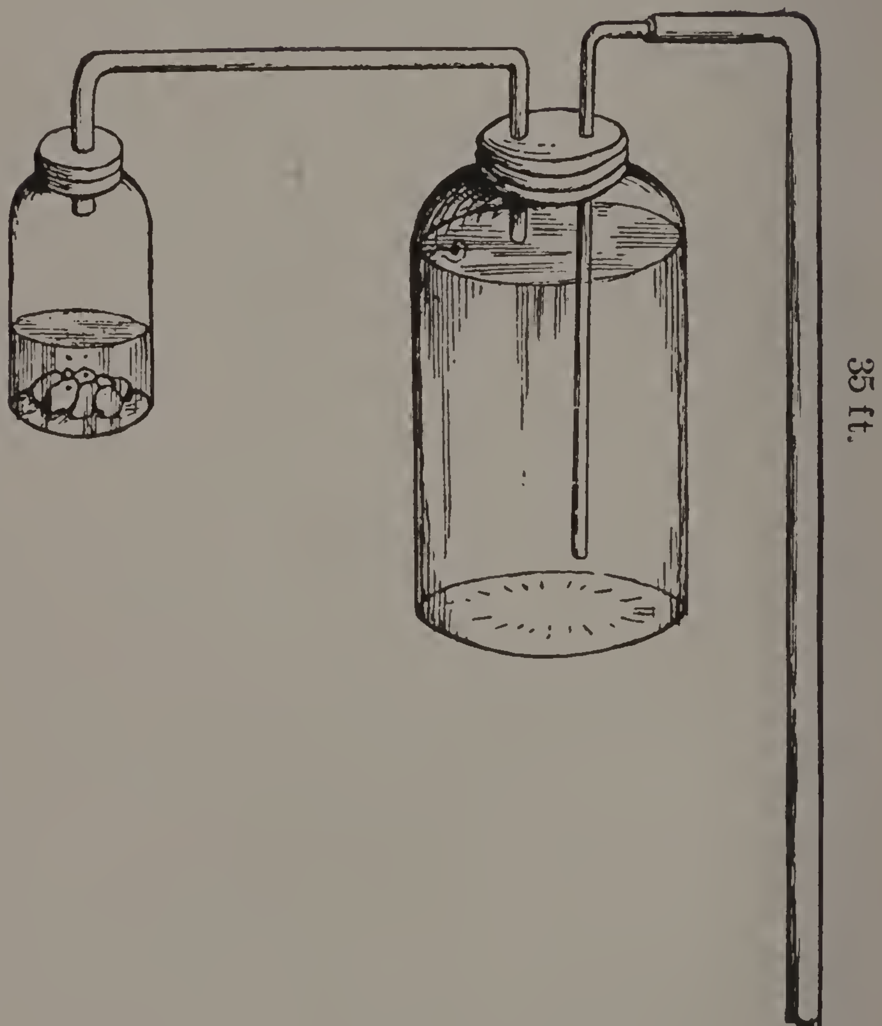


FIG. 50.

With an air pump perform the following experiments: Drill a hole in the small end of a fresh egg and use as shown in Fig. 51.

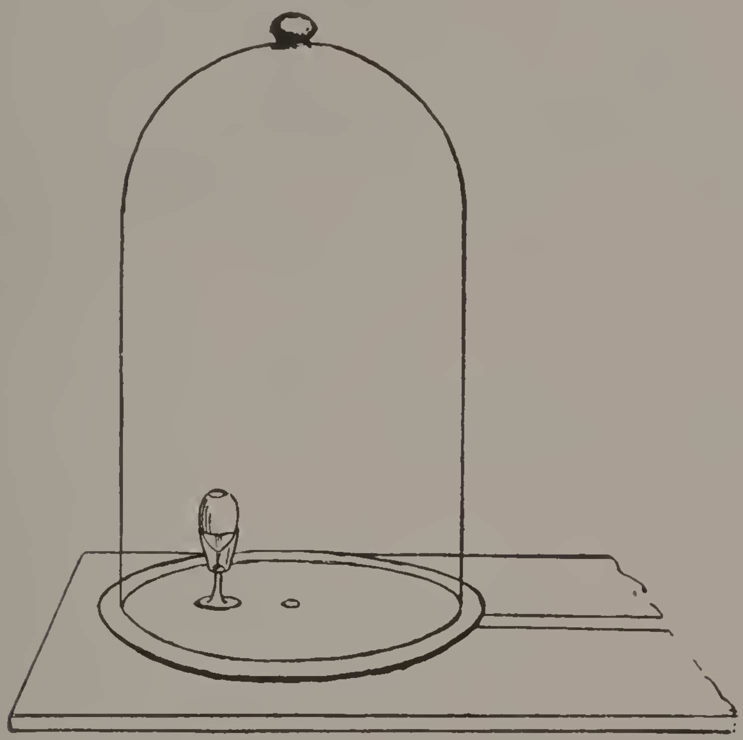


FIG. 51.

Magdeburg hemispheres. (Give history.)

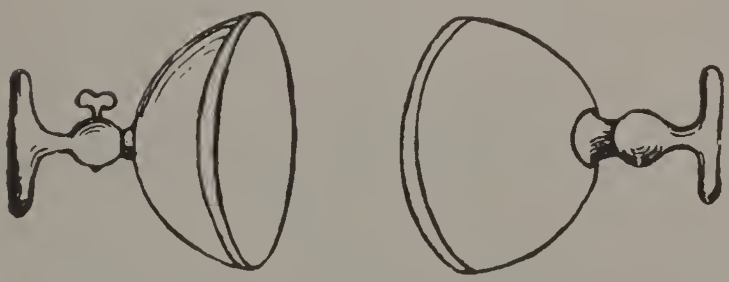


FIG. 52.

What is the air pressure on the hemispheres if their inside diameter is 4 in. and the vacuum is $\frac{7}{8}$ perfect?

Place a perfect apple on the end of a tin apple corer and connect to the air pump, as shown below.

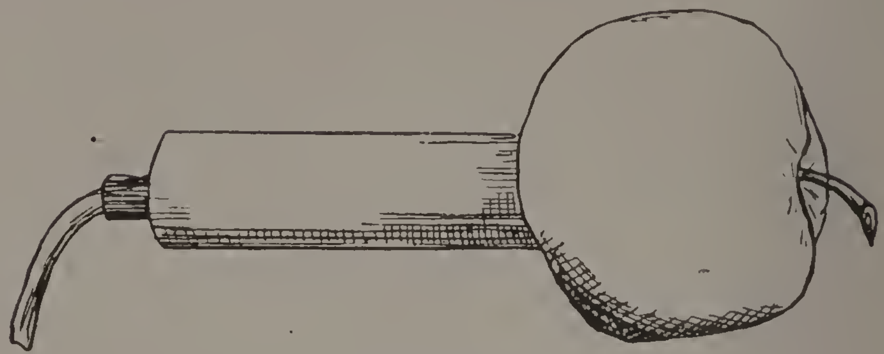


Fig. 53.

TOPICS. Barometer, Manometer, Baroscope, Torricelli's Experiment, Mariotte's Law, Sprengel's Air Pump.

CHAPTER XIII.

MACHINES.

1. Definition.
2. Kinds, a) simple, b) compound.
3. Uses.
4. Friction, a) kinds, b) causes, c) facts.

HYDROSTATICS.

1. Definition.
2. Incompressibility of liquids.
3. Pressure, a) upward, b) downward, c) lateral, d) machines, e) laws, f) problems.
4. Liquids at rest, a) equilibrium—communicating vessels, b) water supply of your city, c) capillarity—capillary tubes—phenomena, d) buoyancy of liquids, e) Archimedes' principle and experiments, f) floating bodies, g) laws, h) problems.

SPECIFIC GRAVITY.

1. Definition.
2. Standards, a) water, b) air, c) hydrogen.
3. Problem, a) dividend, b) divisor, c) quotient.
4. Hydrometers, a) constant weight, b) constant volume, c) for light and heavy liquids.

PROBLEMS.

1. A stone weighs 300 lb., its specific gravity is 2.5. What will it weigh in water?

2. What will 12 oz. of gold weigh in alcohol whose specific gravity is .8?

3. A piece of lead weighs 120 gr. in air and 109 gr. in water. What is its specific gravity?

4. A fresh egg in a pint of water sinks. How much salt must be added to the water to float the egg? What % salt is the water? (A saturated solution of salt is 100 % salt.)

5. A piece of cork displaces 2 lb. of water. What is the weight of the cork?

6. A man weighs 150 lb. in air and 1 lb. in water. What is his specific gravity?

7. An overturned boat will support more persons in the water than it will carry. Why?

8. A lamp has a short wick. The oil may all be burned out. How? State the principle.

9. The specific gravity of cork is .24. How much lead must be placed upon a cu. ft. of cork to sink it?

10. A lighter 30 ft. wide and 50 ft. long and in the form of a box draws $3\frac{1}{2}$ ft. of water when loaded and 1 ft. when empty. What is the weight of its load?

CHAPTER XIV.

HYDRAULICS.

1. Definition.
2. Flow through pipes, a) velocity—law—formulæ, b) quantity discharged, c) bursting pressure.
3. Flow through orifices, a) head, b) velocity, c) quantity discharged, d) orifice of greatest range.
4. Water wheels, a) Barker's mill, b) turbine.

PROBLEMS.

1. In laying water mains right angles are avoided. Why?

2. A reservoir is 150 ft. above the river. One pipe is used for its supply by a pump and for distribution therefrom to the city. Can the pump work and the city be supplied at the same time? Explain.

3. How long will it take to empty a cubical tank which is 5 ft. on edge (inside), from a hole 1 in. in diameter in its bottom?

4. Explain the Tantalus cup.

5. What is meant by the Holly system of water pressure?

6. Give the reasons for the noise made by closing suddenly the faucet when the water is running.

7. Does water flowing freely through a vertical pipe exert any lateral pressure? Why? Show by diagram.

8. Water spouts from an orifice with a velocity of 80.4 ft. per second. What is the head?

9. A faucet $\frac{3}{8}$ in. in diameter is left open. How many gallons of water is discharged in one hour with a constant head of 60 ft.?

10. What five hindrances to the flow of water through and out of pipes?

CHAPTER XV.

HEAT.

1. Definition.
2. Temperature, a) thermometers, b) graduation, c) thermometric scales, d) rules for changing readings, e) absolute zero of temperature.
3. Expansion, a) in solids, b) in liquids, c) in gases, d) proofs of each.
4. Liquefaction, a) effect on temperature, b) laws of fusion.
5. Vaporization—effect on heat.
6. Ebullition, a) laws, b) effect of pressure on boiling point, c) culinary paradox.
7. Distillation, a) liquids, b) solutions.
8. Latent Heat, a) of fusion, b) of solutions.
9. Freezing Mixtures—ice machines.
10. Solidification, a) change of bulk, b) liberation of heat.
11. Condensation of gases—heat equivalents.
12. Specific Heat—how determined.
13. Conduction, a) in solids, b) in liquids, c) in gases.
14. Convection.
15. Radiation, a) in vacuum, b) in straight lines, c) in all directions, d) dependence, e) distance.
16. Diathermancy.
17. Absorption.
18. Reflection, a) by mirrors, b) law.
19. Refraction.
20. Steam Engine, a) single acting, b) double acting, c) eccentric, d) governor, e) safety valve, f) condensing engine, g) non-condensing engine, h) heat and work of engines.

CHAPTER XVI.

SOUND.

1. Definition, subjectively and objectively considered—illustrations.
2. Waves, a) causes, b) lines of propagation, c) relation of waves to lines of propagation, d) period, e) length, f) amplitude, g) relation to velocity.
3. Conditions, a) vibrating body, b) transmitting mediums, c) an ear to hear.
4. Velocity, a) in air, b) in other media.
5. Noise—music—scale, relation of its tones.
6. Pitch, a) its dependence, b) proof.
7. Intensity, a) effect of distance, b) law.
8. Transmission—speaking tubes—toy telephones.
9. Reflection, a) experiments, b) echo.
10. Telephone, a) action of, b) transmitter, c) receiver.
11. Phonograph.
12. Sympathetic vibrations.
13. Interference.
14. Beats—capacity of human ear.
15. Laws of vibration of strings.
16. Tones, a) fundamental, b) overtones, c) quality or timbre, d) simple, e) compound.
17. Musical Instruments, a) wind, b) stringed.
18. Define and describe: drum, violin, piano, accordion, Jew's harp, guitar, melodeon, calliope, cornet, bugle, bag-pipe, dulcimer, flute, piccolo, cymbal, whistle, banjo, harp, tambourine, gong, castanets, lute, organ.

CHAPTER XVII.

LIGHT.

1. Definition.
2. Medium, a) what, b) where existent.
3. Relation of bodies to the ether, a) luminous, b) non-luminous.
4. Transmission, a) manner—in straight lines, waves—line of propagation—wave-length—amplitude—relation to line of propagation, b) relation of bodies to transmission—transparent—translucent—opaque, c) forms in transmission—rays, three kinds—beams—pencils, d) velocity in transmission—rate—how, when, by whom discovered.
5. Effects, a) what bodies are seen—the human eye—visual angle, how increased and decreased—failure of the eye to reveal directly, size and distance of objects, b) in coloring of plants, c) inverted images from crossing of rays, d) shadows, definition—umbra—penumbra, e) in photography, f) invisibility of light.
6. Intensity, a) how measured, b) effect of distance, c) law of squares.
7. Reflection, a) definition, b) laws, c) apparent direction of visible bodies—cone of rays—intersection of two rays, d) mirrors—definition—plane—concave, principal axis, principal focus, center of curvature, secondary axes, conjugate foci—convex mirror, e) effects, a) real images, b) virtual images—construction of virtual image in plane mirror—in three

possible positions in concave and convex mirrors—construction for real images in concave mirrors—object in three different positions.

8. Refraction, a) definition, b) laws, c) explanation, d) index of refraction, e) critical angle, f) total reflection, g) refractors—three kinds, h) lenses—six kinds—in any lens—principal axis—center of curvature—optical center and how located—conjugate foci, i) effects—real images, magnified and diminished—virtual images, including definition, j) diagrams showing construction for images in each kind of lens, each accurately made and explained, k) spherical aberration—how corrected—the Coddington lens.

9. Chromatics, a) dispersion, definition—solar spectrum—pure spectrum—order of colors—Fraunhofer's lines, b) composition of white light, c) color of bodies, d) the rainbow—conditions—dispersion in a raindrop—reasons for—diagram of bow—secondary bow—reasons for its position—diagram, e) chromatic aberration—achromatic lens, f) interference, g) diffraction, h) irradiation, i) actinic rays, j) radiation and absorption—relation of one to the other, k) the electric light in photography.

10. Polarization, a) definition, b) planes of vibration, c) polarization by absorption—tourmaline plates, d) polarization by reflection—angle for different substances—polariscope—its essential parts—explanation, e) polarization by double refraction——double refracting substances—Nichol's prism—what it is and how made—why so made.

11. Optical Instruments, a) simple microscope—kind of lens—why achromatic—provision for spherical

aberration—position of the object—kind of image—accurate diagram of lens, object, rays and image, b) compound microscope—monocular—binocular—stand—stage—mirror—objective, eye-piece, apparatus for focusing—diagram presenting sectional view of all parts of the compound microscope, also showing object, path of rays, and image, c) telescope—refracting—the refractor—eye-piece—location of several such telescopes—reflecting telescopes—name and location of one, d) opera glass—diagram presenting a sectional view of instrument and showing, also, object, path of rays, and image—explanation of same, e) stereoscope, a) how lenses are placed—diagram with explanation—manner of taking photographs for stereoscope, f) magic lantern, g) solar camera, h) kaleidoscope, i) common spectacles—give accurate diagrams presenting a sectional view of lens and human eye, showing also object, path of rays to the retina, and effect of lenses of different curvature.

CHAPTER XVIII.

MAGNETISM.

DEFINITION. **Magnetism is electricity in rotation.** This is shown by the way a magnet acts.

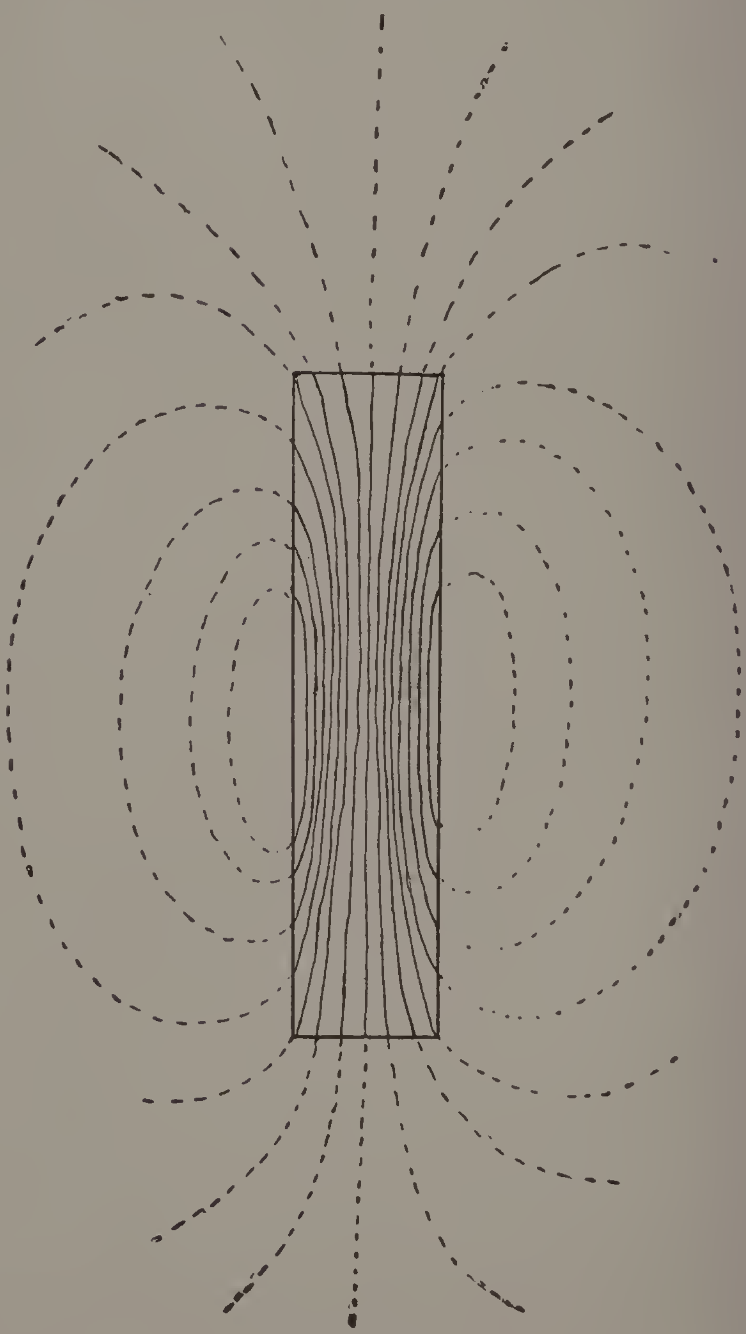


FIG. 54.

That a magnet acts in this way may be seen by placing a magnet under a sheet of paper on which are some iron filings.

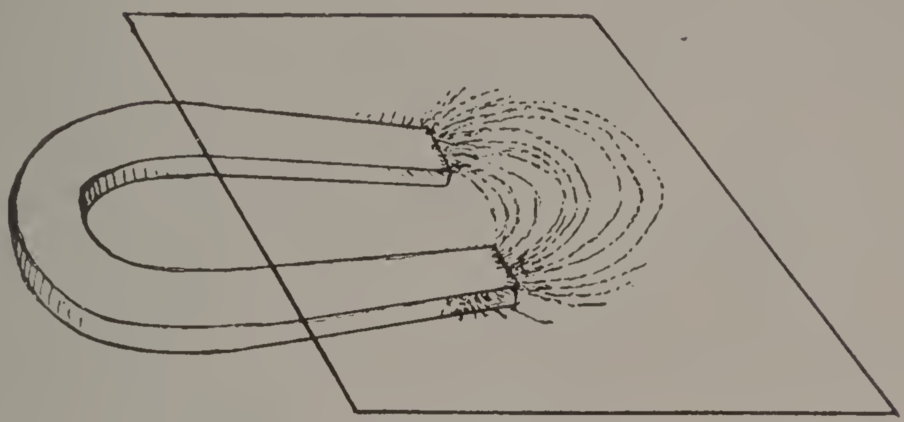


Fig. 55.

MAGNET. The word magnet comes from Magnesia, a town in Asia Minor, where the lodestone was discovered.

DEFINITION. A magnet is a mass of polarized molecules.

By division and subdivision of a magnet, it is proven tnat each part, however small, is a magnet.

Plunge a white hot watch spring into cold water. Magnetize it by rubbing it one way with a lodestone or a magnet.

Break it in pieces. Each part shows polarity.

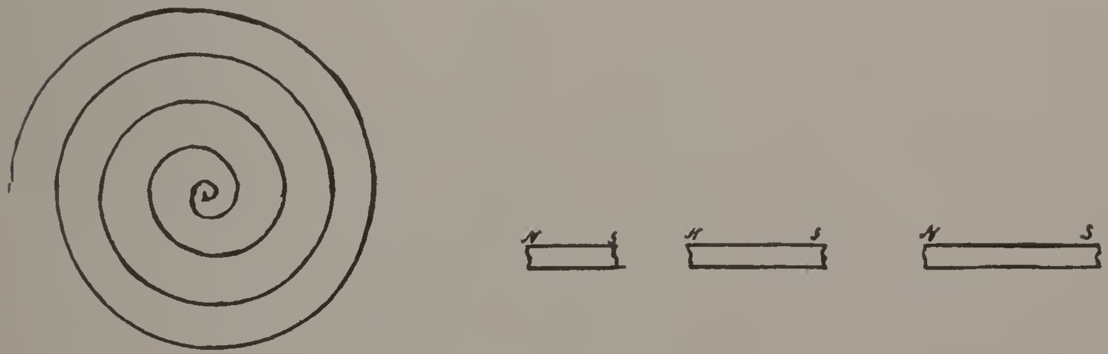


Fig. 56.

KINDS. Magnets are natural or artificial. Natural magnets are of meteoric origin. They are magnetic oxide of iron and are represented by $Fe_3 O_4$.

SUSPENDED MAGNET. If a natural magnet be suspended as shown, it will point N. and S.

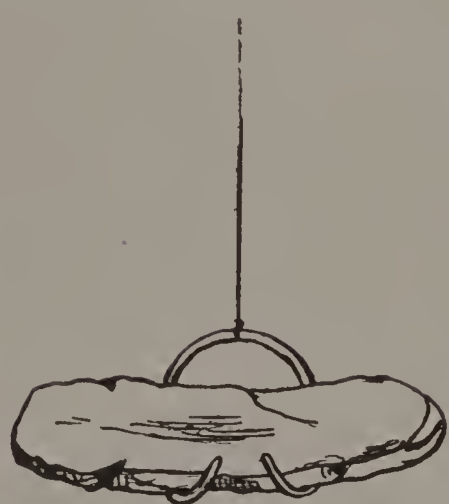


Fig. 57.

Fig. 58.

REASON. All the molecules of the magnet being polarized face each way from the center. This polarity increases to points near its extremities. The influence of the earth as a magnet causes the north-seeking pole to turn to the N. magnetic pole of the earth—from the law: **Like poles repel and unlike poles attract.**

From the above it appears that the magnetism of either pole is the opposite of that indicated by its sign.

By balancing, find the axis of a croquet ball. Closely fit a $\frac{3}{8}$ in. magnetized steel rod in a hole bored through the axis, the magnet terminating at the surfaces.

If suspended with the magnet horizontal, the latter

will take position in a magnetic meridian of the earth and point N. and S. The ball now fairly represents the earth and its magnetic poles.

With a natural or artificial magnet, magnetize by rubbing one way only, a knitting needle.

Suspend the needle over the globe in a position parallel to the enclosed magnet, and notice the position taken by it.

This experiment illustrates the statement concerning the earth as a magnet.

SIGNS ON MAGNETS. The north-seeking pole of a magnet may be marked N +, or with a notch.

The south-seeking pole bears opposite signs or is unmarked.

However marked, the magnetism of the pole is opposite to that indicated by its sign.

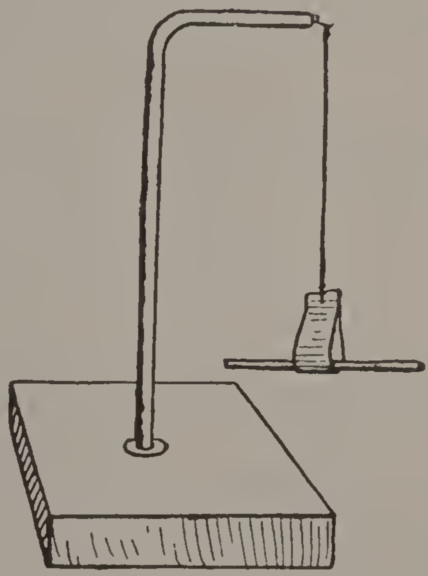


FIG. 59.

Determine from the above figure the poles of a magnetized knitting needle by testing with a common magnet. **Mark the poles.**

HOW TO MAKE A MAGNET. Take two bar magnets and use them as indicated in

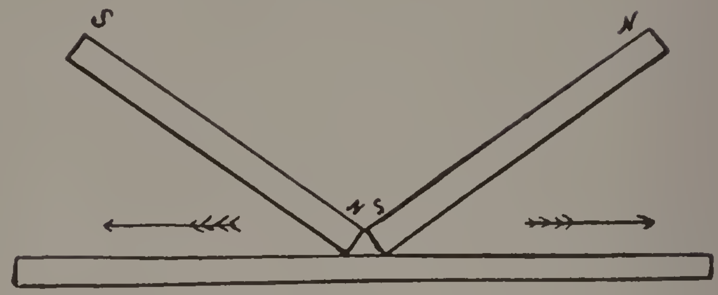


FIG. 60.

Draw the magnets from the center of the unmagnetized bar to its ends and carry them back to repeat the action.

Do this a dozen times on opposite sides of the bar, terminating the last stroke at the center of the bar.

Mark the poles and test as indicated in Fig. 59.

II. Use a horseshoe magnet as indicated in

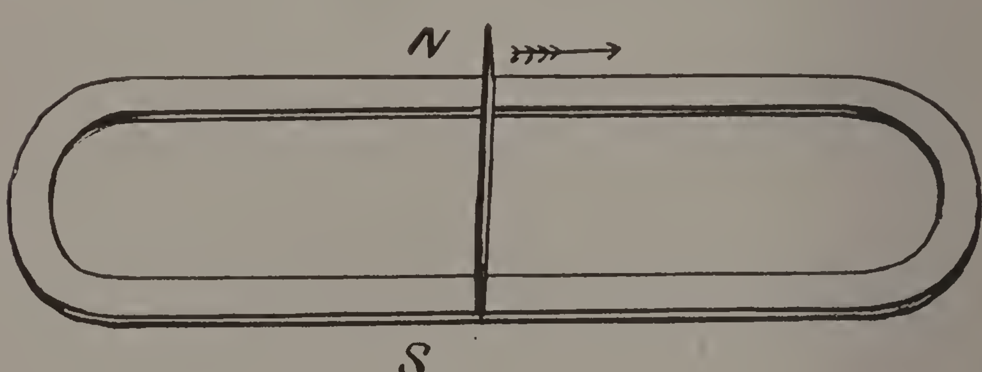


FIG. 61.

Repeatedly draw the short piece of soft iron from the center of the magnet to the center of the bar.

Make each stroke the same way.

Without separating the poles of the magnets, invert them and repeat the strokes until the bar is saturated.

SATURATION. By saturation is meant that the molecules have received all the magnetism they can retain.

RETENTIVITY. The retentivity of a magnet is its power to retain magnetism.

The retentivity of iron is little, that of steel is great.

Iron receives and parts with magnetism quickly.

Steel magnetizes slowly and holds it. This is thought to be due to the fixedness of its molecules.

The freedom of motion of the molecules in liquids prevents retentivity.

Magnetize mercury. Upon the withdrawal of the magnetizing force its molecules rearrange themselves as before magnetization.

DEPTH OF SATURATION. Not all the molecules of a magnet are saturated. Only a shell of such molecules exists.

This may be proven by dissolving this outer coat with sulphuric acid, when the remaining bar is found to have no magnetism.

For this reason a bar to be magnetized is turned over in the process.

LOSS OF MAGNETISM. Magnets lose their power in three ways:

1. By unprotected poles.
2. By blows or jars.
3. By heat or cold.

Treat magnets of your own make in the above ways for proof.

HOW TO KEEP A MAGNET. For a bar magnet place a piece of soft iron on each pole.

For a horseshoe magnet cover both poles with a short bar of soft iron called an armature.

An armature completes the magnetic circuit and prevents loss of magnetism. Such an armature is temporarily magnetized, each end having opposite magnetism to the pole it joins.

Not only may the power of a magnet be retained, but its power may be increased.

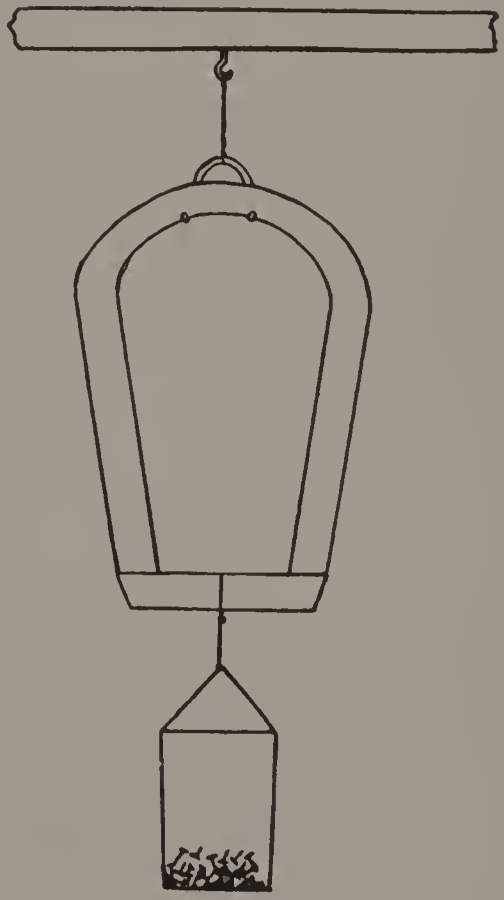


Fig. 62.

Load the can as shown with all the nails the magnet can support. Each day add more. In this way Sir Isaac Newton caused a magnet to support two hundred times its own weight.

Carefully remove the load. The magnet loses its increased magnetism, returning to its former condition. This is thought to be due to a change in the position of the molecules assumed by them upon the removal of the strain.

LINES OF FORCE. The lines of force are lines along which the magnetism acts.

These are curved lines extending from pole to pole, and on all sides of the magnet. Those nearer the magnet form closed circuits.

FIG 63.

This may be shown by experiment. Plunge a round bar magnet into iron filings of varying degrees of fineness. They assume positions in the lines of force.

FIG. 64.

MAGNETIC FIELD. The magnetic field of a magnet is the space through which the lines of force pass.

The magnetism in this field is strongest nearest the magnet.

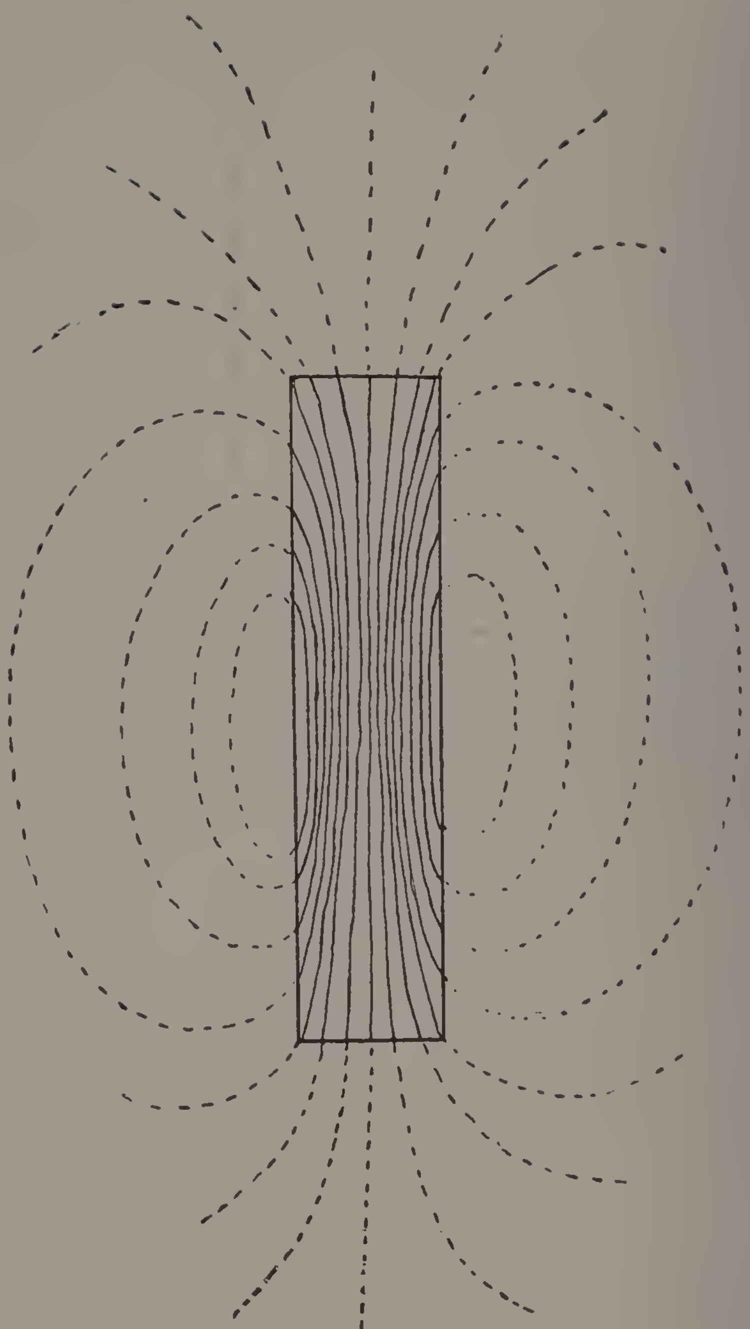


FIG. 65.

Hence the following laws:

I. Magnetism decreases as the square of the distance from the poles increases.

II. The force between any two magnetic poles is equal to

the product of the numbers representing their strengths divided by the number representing the distance between them.

SELECTIVE POWER. If a magnet be applied to a mass of brass and iron filings, mingled with sand and saw-dust, it will select the iron only.

A MAGNETIC BODY. A magnetic body is one that is attracted by a magnet. Paper, pith and cotton are feebly magnetic under the influence of a powerful magnet.

LIFTING POWER. The lifting power of a magnet depends upon:

1. Its form.
2. Its strength.

A horseshoe magnet will lift twice as much as a bar magnet of the same size and strength because the magnetism of both poles acts upon the weight at the same time.

FORM OF MAGNET. The form of a magnet has reference to:

1. Its general shape.
2. The shape of its ends.

GENERAL SHAPE. The most common form is that of a horseshoe, because of its convenience, lifting power, and use of single armature or keeper.

SHAPE OF ENDS. Common magnets are flat, with a thickness varying from $\frac{1}{5}$ to $\frac{1}{3}$ of the width.

This form coincides best with the form of the ideal magnet, which is a bar so thin that all of its molecules are polarized.

STRENGTH. The strength of a magnet is the force exerted by one of its poles.

From this it appears that the lifting power of a magnet is not less than twice its strength.

Test this as suggested in

FIG. 66.

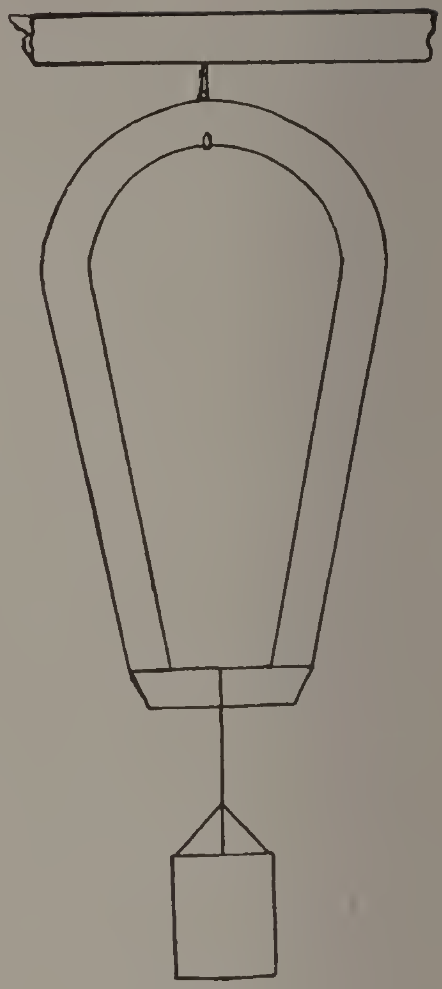


FIG. 67.

FACTS. 1. Magnetism and electricity are identical. Mendenhall in "A Century of Electricity," p. 75.

2. Magnetism may be hastened or lost by jars or torsion. Atkinson in "Dynamic Electricity," p. 54.

3. Magnetism is strongest at the poles and **nil** at the center. Silliman in "Principles of Physics," p. 510.

4. A piece of steel magnetized and demagnetized is not in the same condition as at first. Lodge in "Modern Views of Electricity," p. 162.

5. **Magnetism cannot be insulated.** "Modern Views of Electricity," p. 152.

6. Magnetized spheres and circular disks have no distinguishable poles. "Dynamic Electricity," p. 63.

CAUTIONS. 1. A magnet should be kept, poles downward, in the magnetic meridian.

2. The poles should be covered with an armature, which should be placed on and taken off with a gentle, sliding motion.

3. Do not handle a magnet rudely. Avoid jars or shocks caused by dropping or by blows.

4. Do not subject a magnet to extremes of heat or cold.

THEORIES. The oldest theory supposes that all bodies are permeated by two electrical fluids, which are mutually attractive and repellent.

Combined they are neutral. Magnetization separates these fluids. (Franklin.)

A later theory supposes that each molecule of a magnetic body has a current of electricity circulating around it, thus:

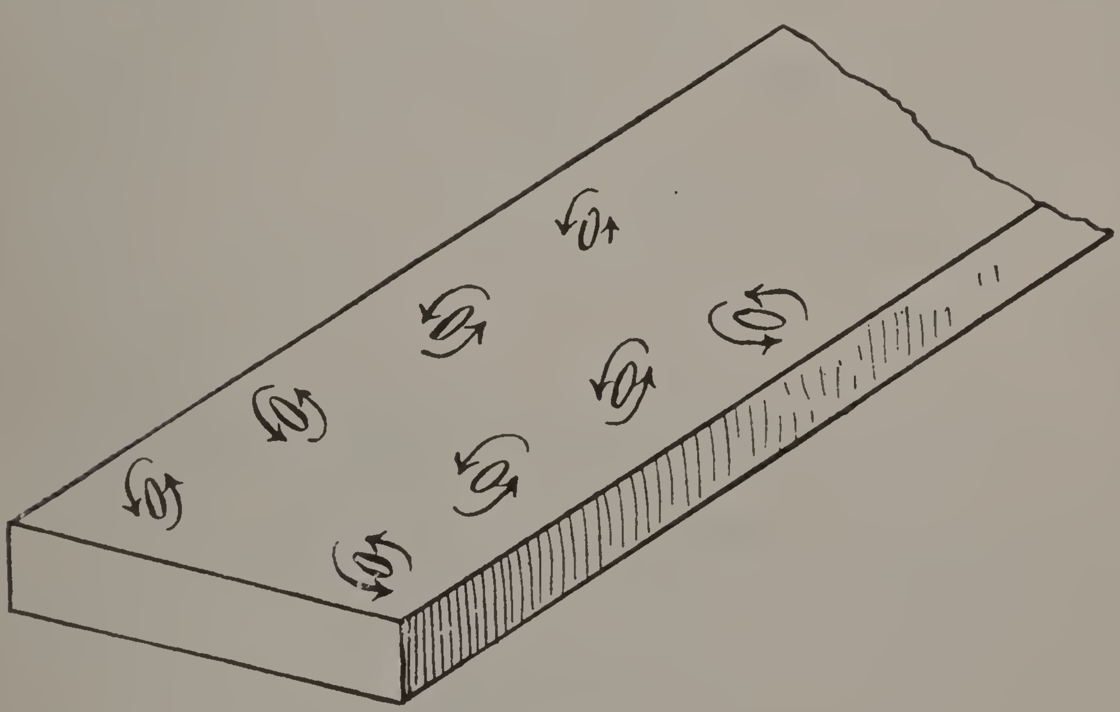


FIG. 68.

(Ampere.)

These currents before magnetization circulate in different directions, owing to the positions of the molecules, and there is produced, therefore, no external effect.

After magnetization these currents circulate in the same relative direction and the molecules now face about and look along the lines of force.

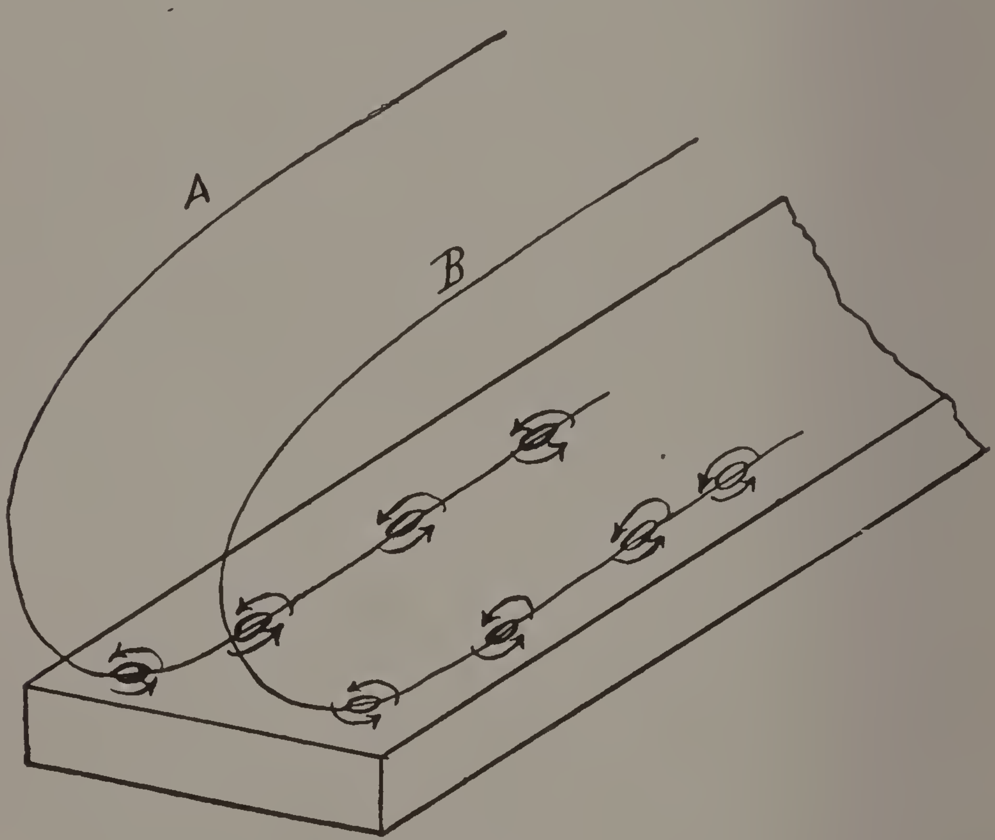


FIG. 69.

The act of magnetization consists in changing the positions of the molecules so that the effect of their combined magnetism is manifested by the bar as a whole.

Magnetization adds no magnetic force to a body.

SUPERSTITION. Pliny believed that the word magnet was derived from Magnes, a herdsman who found himself held to a magnetic rock by the nails in his shoes and the iron in his staff.

The ancients used magnets to suspend statues in their temples to awe the worshippers.

Mahomet's coffin "soared" in a sanctuary of magnetic stones.

It is a popular belief in Japan that magnets lose their power just before earthquakes.

Magnets are credited with medicinal and revealing powers, such as curing diseases and revealing secrets.

Superstition claims that a magnet may reveal the motives of a bride in the choice of her husband.

Superstitious notions of the form and attractive power of the magnet have survived the past.

Good luck is believed to come to that American home whose walls are decorated with the object, the image, or the picture even, of a horseshoe.

CHAPTER XIX.

INDUCTION.

In the foregoing work on magnetism, induction has been implied in all the theory and has formed the basis for nearly all of the work.

Topics are so closely related in science work that no one of them can be fully treated alone.

DEFINITION. Induction is the process of developing magnetic or electric phenomena through the agency of lines of force.

If a body is magnetized or electrified by induction, it is because of its proximity to a magnet or a current.

That magnetism and electricity are identical, may be

shown by suspending a magnetized knitting needle as in

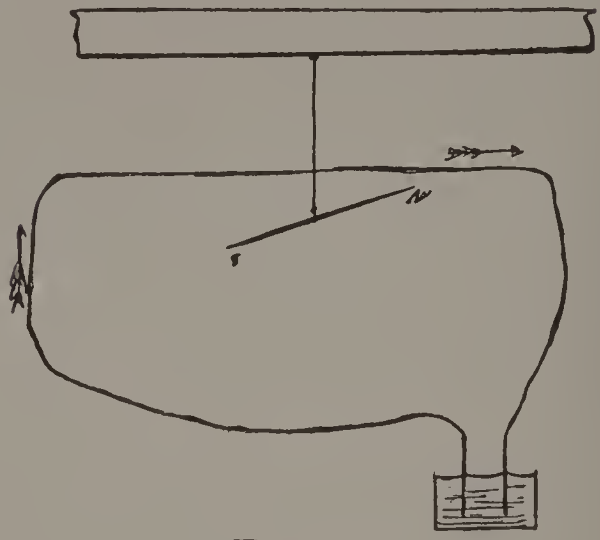


Fig. 70.

Place a wire joining the two poles of a battery under or over and parallel to the needle.

It instantly turns to a position at right angles to the wire.

Since magnetism is electricity in rotation, and since a current of electricity is brought parallel to a freely moving mass of polarized molecules, the position of the magnet is what we should expect.

Oersted's experiment before his class. "A Century of Electricity," p. 76.

CHAPTER XX.

INDUCED MAGNETISM.

Bring one pole of a magnet into contact with a piece of soft iron and this into contact with some iron filings.

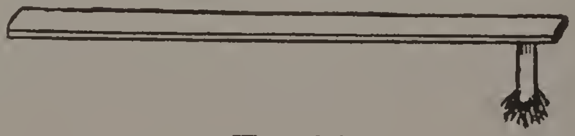


Fig. 71.

Hold the iron a short distance from the magnet as indicated in

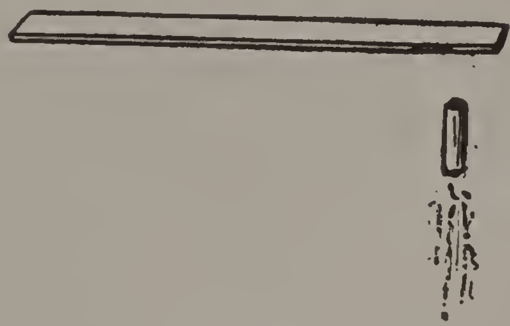


FIG. 72.

Arrange a magnet, bar and needle as indicated in

FIG. 73.

Portative magnetism.

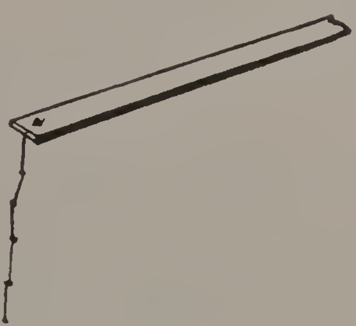


FIG. 74.

TERRESTRIAL MAGNETISM. Suspend a magnetized bar from its center in a room free as possible from iron or steel and free from air currents. Allow the bar to come to rest. It points to the north magnetic pole of the earth,

and by its position indicates a magnetic meridian of the earth.

MAGNETIC MERIDIAN. **A magnetic meridian is a meridian whose position is indicated by a line of force extending through the magnetic poles.**

What does the needle of a pocket compass indicate by its position when it is at rest?

VARIATION. **The croquet ball.** On the croquet ball represented in Fig. 67a, establish a point representing the earth's north geographical pole from the following:

1. Let the north-seeking pole of the enclosed magnet represent the north magnetic pole of the earth.

2. The north magnetic pole of the earth is in about 70° north latitude.

From this it appears that the north magnetic pole of the earth is about 20° south of its north geographical pole. The position of the south magnetic pole has not been accurately determined.

Next establish a line representing the earth's equator and a point representing its south pole.

Draw several lines extending from pole to pole representing geographical meridians, one of which passes through the geographical and magnetic poles. The ball now represents the earth.

On the ball select a meridian which does not pass through the magnetic poles.

On the meridian select a point north of the equator.

On this point place a pocket compass with the center of its needle directly over it.

Allow the needle to come to rest. It indicates the position of a magnetic meridian.

The angle formed at the point selected by the intersection of the two meridians is the angle of variation for that point.

If the center of the needle be moved along the geographical meridian toward the north pole it will be seen that the angle of variation increases. Why?

Place the compass on a point in the meridian which passes through both poles. Explain the result.

In a similar manner, place the compass on different meridians, noticing that the needle points east or west of the north geographical pole.

Would the needle point east or west of the true north if placed on the meridian passing through the place of your residence? How much? Approximately measure this variation in degrees.

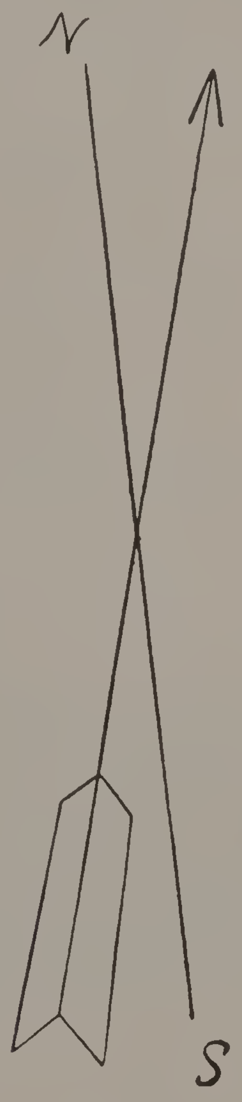


FIG. 75.

In 1890, the variation for San Francisco was 16° 34′ E.

DIP OF THE NEEDLE. Suspend and balance a small magnetized darning needle. When it is at rest bring the north magnetic pole of the ball under the point of suspension.

The needle takes a vertical position.

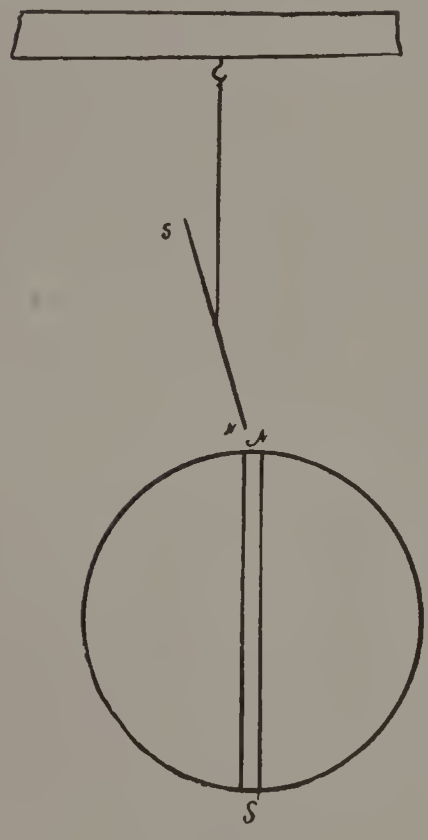


FIG 76.

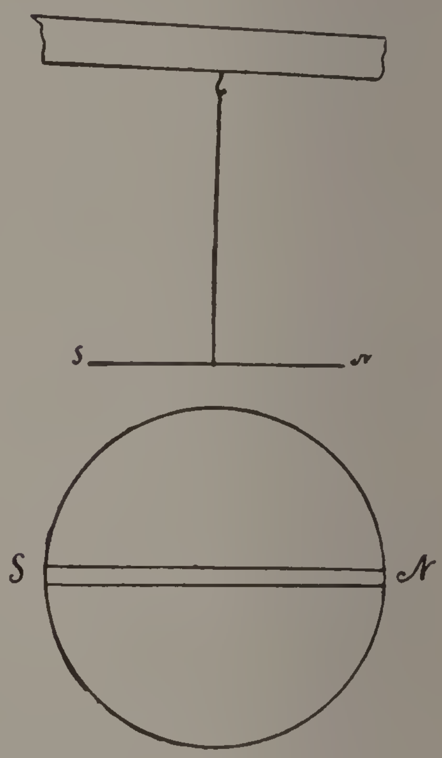


FIG. 77.

When the magnet is in a horizontal position the needle is nearly so and tangent to the ball at its equator.

Turn the ball so that the needle may come under the direct influence of the south magnetic pole.

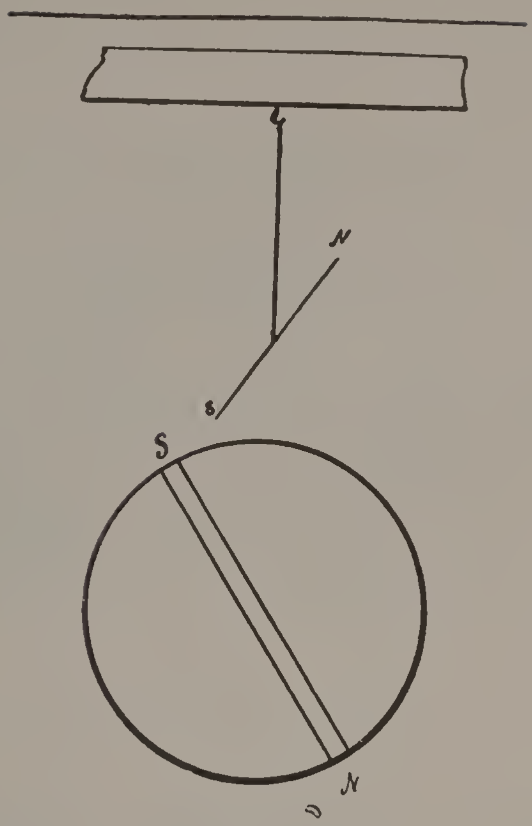


FIG. 78.

(N. and S. on the needle indicate north and south seeking poles.)

Leave the needle suspended in a closed room, free from iron and steel, during the night. In the morning, notice its dip.

The dip of the needle for San Francisco in 1885 was 62° 15′.

Of what value to the surveyor and mariner is a knowledge of the variation of the needle, or its dip?

The illustration of the ball and needle has been given for the reason that it points along divergent and interminable, though interesting, lines of thought which the wise teacher must judge when and where to cut off.

CHAPTER XXI.

ELECTRICITY.

DEFINITION. Give the etymology of the word.

Just what electricity is, is still unknown.

By many, it is believed to be a form of energy; others claim that it is a mode of molecular motion.

Our most advanced thinkers incline to the belief that it is a substance.

More will be said about this further on.

Our best way is to play with it.

EXPERIMENTS. There exists a notion that simple experiments should be discarded. They should be encouraged, rather.

No topic in science presents phenomena so wonderful and through the use of apparatus so simple as electricity.

It is hoped that teacher and pupil will multiply illustrations until the principle stated is fully understood.

In all experimentation, one thing suggests another, and this inquiry on the part of the pupil for more light and new proof is investigation.

FRICTIONAL ELECTRICITY. Frictional electricity is electricity developed by mechanical excitation.

Its phenomena are classed under attraction and repulsion.

ATTRACTION. Rub a vulcanite ruler or rod with a flannel. Bring it near a lead pencil suspended as indicated in

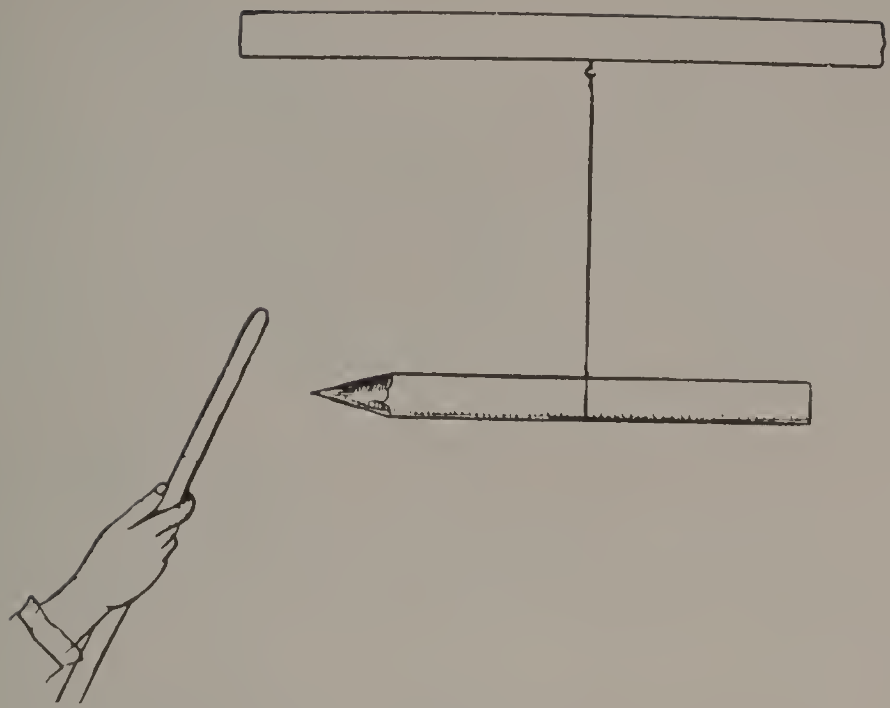


FIG. 79.

In like manner approach the pencil with a stick of sealing wax, a roll of sulphur or a glass rod after rubbing each with a dry flannel.

Apply the same electrified bodies to bits of paper, pith or feather clippings. Why are these attracted?

All bodies have electricity and are conductors or non-conductors of it.

The terms electrics and non-electrics are evidently inapplicable.

ELECTRIFIED BODIES. An electrified body is one that manifests electricity.

EXCITANTS. That which is used as a rubber is called an excitant.

Repeat these experiments, using the excitants as electrified bodies. What happens?

Bring an electrified glass rod near bits of paper, as indicated in

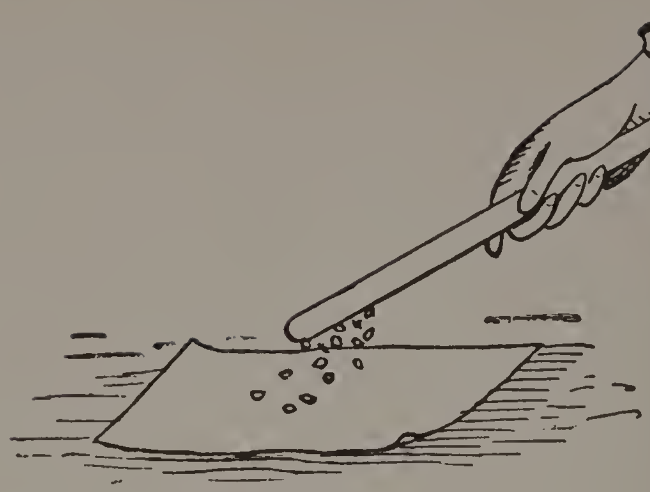


Fig. 80.

What happens to such bits as touch the glass? Why? State the law of attraction and repulsion.

Split a lath lengthwise and suspend one half as indicated in

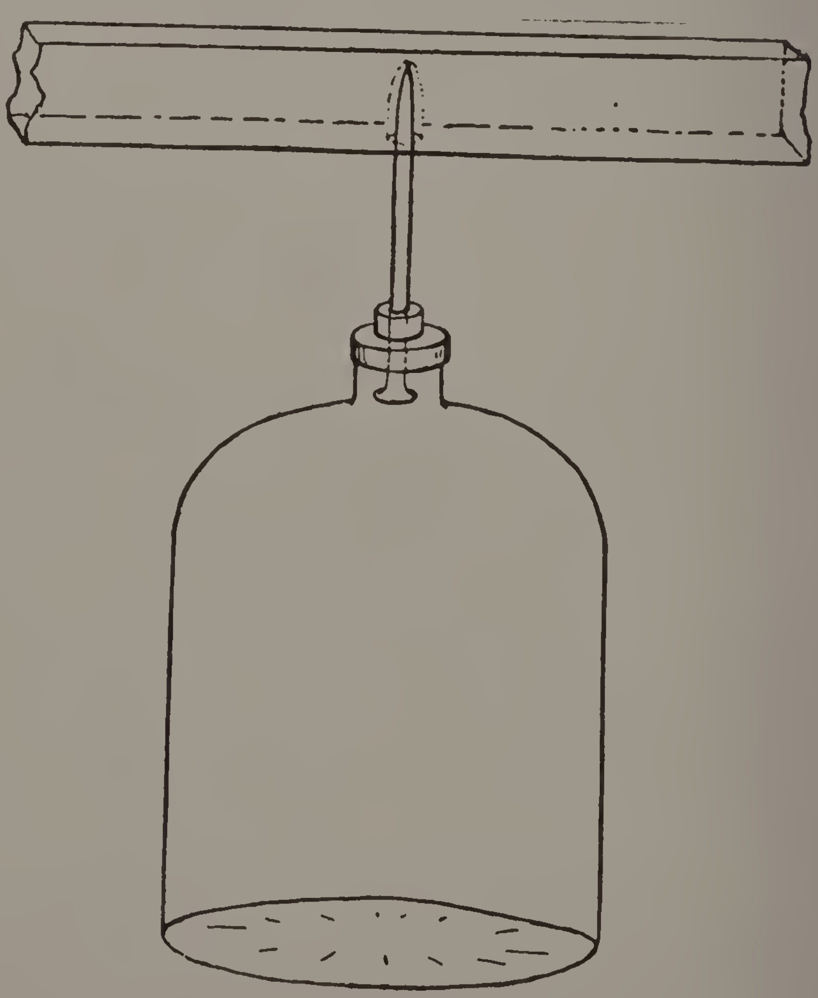


Fig. 81.

This lath, as adjusted, may be made to show attraction and repulsion. How?

From the above experiments it appears that unlike substances undergoing the same act have manifested forces of equal strength and opposite in character.

Shall we say that the act has developed positive and negative electricities? Perhaps not.

The terms positive and negative imply a standard of comparison.

STANDARD. What is the standard?

All electricians refer to the electric condition of the earth for a standard of comparison.

This electric condition of the earth is rated zero.

Bodies having the same electric condition as the earth are without electric potential.

Such bodies as are in a higher electric condition have positive potential. Those lower, negative potential.

Electric potential is the difference in the electric conditions of two bodies compared. This difference may be one of intensity or quantity.

The electric condition of a body may be referred to that of another, or to that of the earth.

Experiments in Static Electricity ignore the electric condition of the earth except as communication with it favors or hinders the experiments.

ATTRACTION AND REPULSION. Attraction and repulsion are but manifestations of states of potential.

Bodies of like potential repel and those of unlike potential attract.

These statements do not **explain** attraction and repulsion.

Just why electricity, in passing from a body of a higher potential to one of lower, causes attraction, or why

two equally electrified bodies cause, upon their approach, repulsion, is something that future investigation will shed more light upon.

Modern writers incline to believe with Franklin, that there is one kind of electricity, and that all electric phenomena are the result of having taken it from one body and put it into another.

Let us try another experiment.

CHAPTER XXII.

THE ELECTROSCOPE.

First prepare a gold leaf electroscope with which to test electric potential.

Thoroughly dry a quart bottle and hang a strip of gold leaf on a brass rod as indicated in

FIG. 82.

CAUTIONS. a) The stopper of the bottle should be of insulating material. b) The leaves should not be long enough to reach the sides of the bottle.

With the bodies and excitants already used, test the relative kinds of potential.

Higher relative potential is positive, and is indicated by the sign +.

Lower relative potential is negative, and is indicated by the sign −.

AN ELECTROSCOPE SHOWS:

1. The presence of electricity.
2. Its relative amount.

It will be found on further use of the instrument that different degrees of the same potential increase or decrease the divergence of its leaves.

From this it appears that the electroscope does not reveal the potential of a body with respect to that of the earth.

It only shows the amount that one body has when compared with that of another.

The electroscope proper is the disk, the rod, and the suspended leaves.

The bottle is simply for protection and support of the electroscope.

If the electroscope be put in direct communication with the earth and its disk be approached by any electrified body, its leaves diverge.

In this case, electricity passes to or from the earth, causing the divergence of the leaves.

The direction which it takes is the true test of electric potential.

Now try the following experiment: Fit a flannel cap over a vulcanite rod as indicated in

FIG. 83.

Twist the rod in the cap and remove it with the silk thread. Bring the cap by its thread near the disk of the electroscope to test its potential.

Notice divergence.

Bring the rod near the disk.

Notice convergence.

The rod is negatively charged with respect to the flannel.

The same act has developed potentials of opposite characters.

Shall we say opposite electricities?

Will it not be more consistent to say opposite potentials, and attribute the phenomena to the difference in degree of electrification of the bodies used, due to their difference in constitution?

This is the belief of Mr. Atkinson, whose recent works on electricity are attracting much attention.

Let us now represent the cap folded and the rod cut off to the same length as indicated in

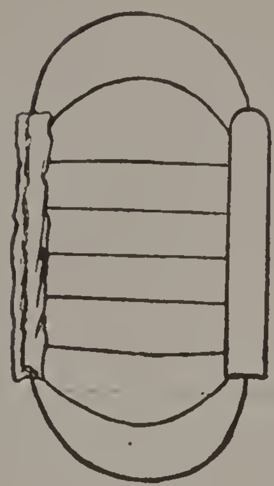


Fig. 84.

Lines of force may be considered as existing between the two bodies, as was shown in the magnet.

Upon the wider separation of these bodies the representation would be as indicated in

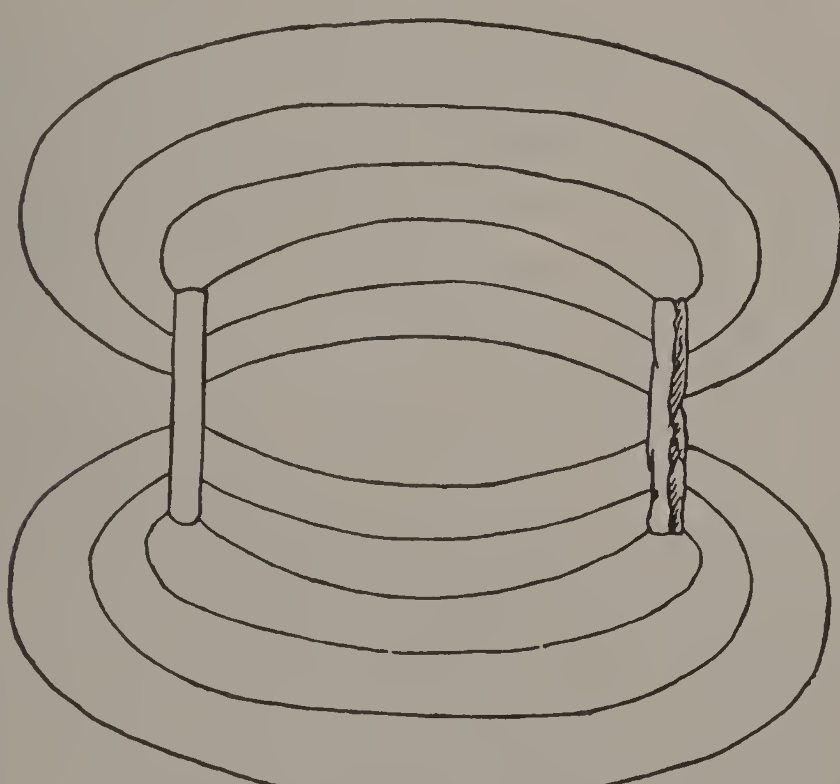


Fig. 85.

A line of force is a line along which electricity passes from

a point of higher to one of lower potential. (See experiment illustrating this under Galvanic Electricity.)

Insulate a lead pencil and join its lead to the electroscope, as indicated in

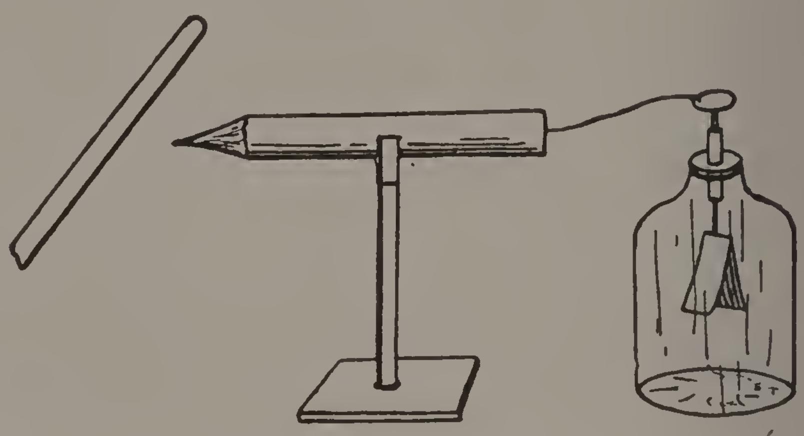


FIG. 86.

Approach the exposed lead with a body of negative potential.

The result is indicated in the drawing.

The lead of the pencil has conducted the electricity to the electroscope.

CONDUCTOR. A conductor is a body that favors the transfer of electricity.

If the experiment be repeated with a short stick and the connections made as before, the experiment will fail.

The wood of the stick offers resistance to the transfer of electricity, or is a non-conductor of it.

NON-CONDUCTOR. A non-conductor is a body which offers high resistance to the transfer of electricity.

The best conductors are silver, copper, iron, and zinc.

The poorest conductors are vulcanite, rubber, glass, wood and paper.

The standard of conductivity is that of silver. It is

rated at 100. Copper is then rated at 73, brass at 22, iron at 13.

Copper, iron, and brass are the most important metals used in the practical application of electricity.

For additional experiments with the electroscope, see Poyser in "Magnetism and Electricity."

For the more complete mastery of this instrument, see Atkinson in "Static Electricity."

CAUTIONS. The two most important cautions in the foregoing experiments are those regarding temperature and insulation.

The bodies used and the surrounding air must be dry.

Rubber corks, shellac, vulcanite, and paper are the experimenter's friends in this work.

The open secret in all successful experimentation in frictional electricity is **insulation.**

INSULATORS. An insulator is a non-conductor used to confine electricity within certain limits.

The value of insulation cannot be overestimated in all successful work with electricity.

Along the line of effort to bring electricity to practical uses, perhaps no topic concerning it has been more thoroughly investigated or more successfully mastered than this one of insulation.

In fact, each pupil should be on his guard in every electric experiment lest this subtle force escape his grasp.

We are not to forget that the best insulator is a feeble conductor.

Oftentimes the apparent behavior of electricity is due to an oversight of the fact that while the air is a universal insulator, it is also a conductor and may manifest all kinds and many degrees of potential.

Further investigation may prove to what extent the divergence of the leaves of the gold leaf electroscope may be due to the surrounding air and glass.

Who has tried the action of an electroscope in a vacuum?

CHAPTER XXIII.

THE ELECTROPHORUS.

Give the etymology of the word and explain its meaning.

DEFINITION. An electrophorus is a miniature electric machine for obtaining a difference of electric potential.

The student should make one.

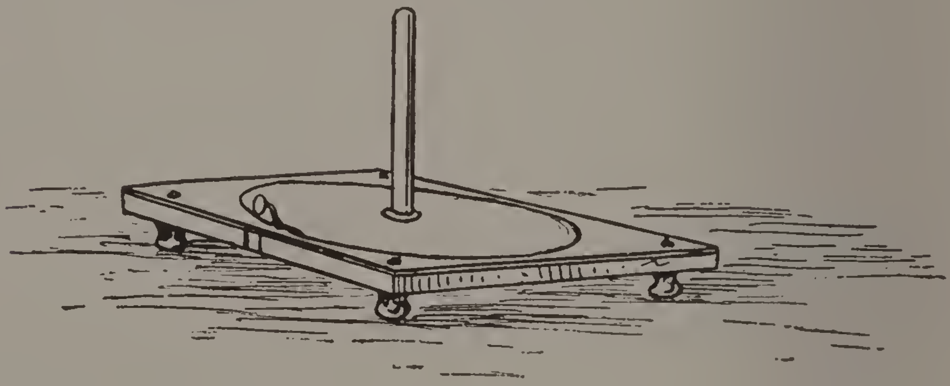


Fig. 87.

Directions for making an electrophorus:

BASE. From dry wood make a base 12 in. square and 1 in. thick, which will not warp. Cut a sheet of tin and one of thin vulcanite the same size. At the middle point of one side of the tin, solder a piece of brass $\frac{1}{2}$ in. wide and 1 in. long.

Fasten both sheets, with the brass beneath, to the base. Bend the narrow strip of brass over the upper side of the vulcanite and extending inward from its edge $\frac{1}{2}$ inch.

COVER. The cover is a circular piece of No. 20 brass $10\frac{1}{2}$ inches in diameter, having a wire carefully soldered to the edge of its upper surface.

A vulcanite handle 7 in. long is fastened to its center by soldering one-half of a $\frac{3}{4}$ in. gas pipe connection to the brass, and screwing the vulcanite into it.

A small brass or other metal ball is fastened to the cover, as indicated in the figure.

USE. Upon beating or rubbing the vulcanite plate with a catskin or a flannel rag, it becomes electrified.

Place the cover on the plate. Bring its edge against the end of the brass strip.

Remove the cover and use it as indicated in

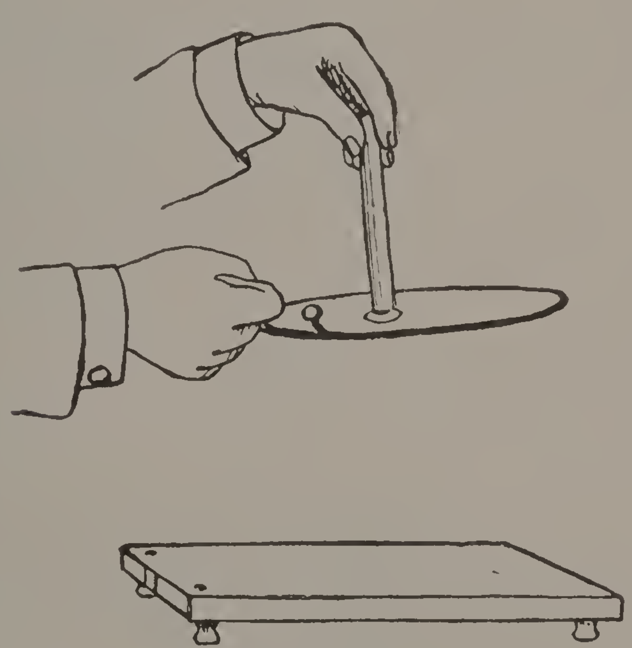


Fig. 88.

EXPLANATION. The plate having been charged negatively by the excitation, a like amount of electricity is attracted from the earth to the under side of the plate and to the upper surface of the brass plate under it, both surfaces being charged positively by induction.

The under surface of the cover becomes positive and its upper surface negative.

Test these surfaces by a proof plane, shown in

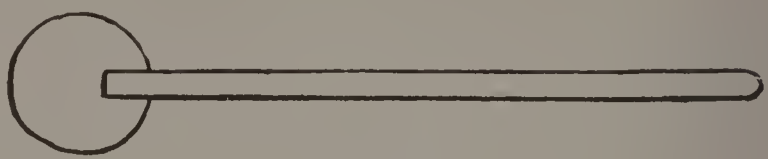


FIG. 89.

The proof plane is made of brass, with an insulating handle.

When the edge of the cover was brought against the end of the brass strip, the accumulated electricity of the lower plate passed to the cover.

The cover becomes positive.

Its charge is bound to the plate while in contact with it.

Upon removal of the cover and applying the knuckle as indicated, a spark is obtained about $\frac{1}{2}$ inch long.

The electrophorus is of great value to the pupil in aiding to an insight into various processes of induction and accumulation of electricity.

If made and used correctly, it is sure to work.

CHAPTER XXIV.

THE ELECTRIC MACHINE

DEFINITION. **An electric machine is an instrument for developing and accumulating electricity by friction.**

No cut or description of it is given.

An electric machine is too difficult for a pupil to make. But he should learn to use it and to explain the general principles of its action.

In all such machines metal brushes are used to develop electricity.

This fact is a strong argument in support of the statement that electricity resides in all bodies. Why?

The following are some of the principles concerning the action of the Toepler-Holtz Machine.

PRINCIPLES. I. A Toepler-Holtz Machine is self-charging and self-sustaining.

II. By a series of inductions electric potential is increased.

III. By conductors and insulators the electricity is led along to the accumulators or Leyden jars.

IV. The electrodes from these jars lead electricity of high, but opposite, potentials, toward each other to form the electric spark.

V. The sources of electricity are the earth, air, and the machine itself.

The full explanation of the electric machine will be possible to that pupil who can recall, apply, and extend the processes of the electrophorus, adding, of course, the explanation of the Leyden jar, which will now be given.

LEYDEN JAR. Explain the word and give its history. See Silliman in "Principles of Physics," p. 558.

HOW TO MAKE A LEYDEN JAR. Select a wide-mouthed half gallon jar of bright green glass.

Candy jars are not good for this purpose because of the conductivity of the glass.

Coat the entire inside and outside of the jar with tin-foil three-fourths of its height.

The coating is best put on with paste.

Leave no open surfaces.

Fit a cover of baked wood to the top of the jar.

Through this put a brass rod, having a ball on its top and a short brass chain attached to its lower end and reaching to the bottom of the jar.

Varnish inside and out all uncovered surfaces.

DEFINITION. **A Leyden jar is an accumulator of electricity.**

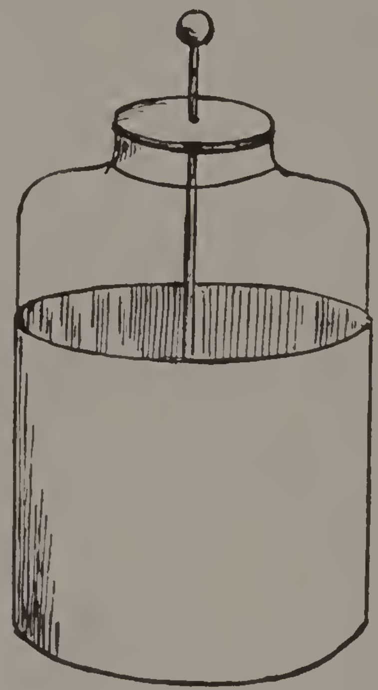


FIG. 90.

CHARGING THE LEYDEN JAR. To charge the jar, place either the inner or outer coating in connection with the prime conductor of the electric machine.

The other coating is to be connected in a convenient way to the earth.

The jar may be charged negatively from the negative electrode.

With the connections made as described and the electrodes of the machine well separated, turn its plate until the jar is "full."

USE. The jar with its charge may now be taken with both hands to any experiment to be made.

The electricity is to be led through the experiment by a discharger.

FIG. 91.

To discharge the jar, place one knob of the discharger to the outer coating and bring the other to the knob of the jar.

EXPERIMENTS. To use the charge of the jar, place the experiment between the outer coating of the jar and its knob by means of conductors that lead through the discharger.

EXPLANATION. The jar is charged positively on its outer coat by holding its knob to the prime conductor of the machine.

This charge repels electricity to the outer coating, which should be in connection with the earth or the negative electrode.

Electricity may be accumulated to such a high degree of potential that the jar may be broken.

For charging the jar negatively, reverse the conditions.

The following typical experiments are stated and illustrated, hoping that the pupil will classify them under the following heads of

CHAPTER XXV.

STATIC ELECTRICITY.

EFFECTS.

1. Attraction.
2. Repulsion.
3. Physiological.
4. Mechanical.
5. Chemical.
6. Luminous.
7. Magnetizing.

DEFINITION OF STATIC ELECTRICITY. Give the etymology of the word static.

Static Electricity is electricity at rest.

It resides only upon the surface of bodies.

TYPICAL EXPERIMENTS. Place a pupil upon an insulating stool as indicated in

FIG. 92.

With the machine charge the pupil.

Draw sparks from this pupil.

Have the pupil place his hand over bits of cotton or over the dry hair of another pupil.

Present to the knuckle of this pupil one end of the balanced lath represented in Fig. 81.

By use of the machine, pass electricity through a piece of insulated tin-foil that supports a common knitting needle, as indicated in

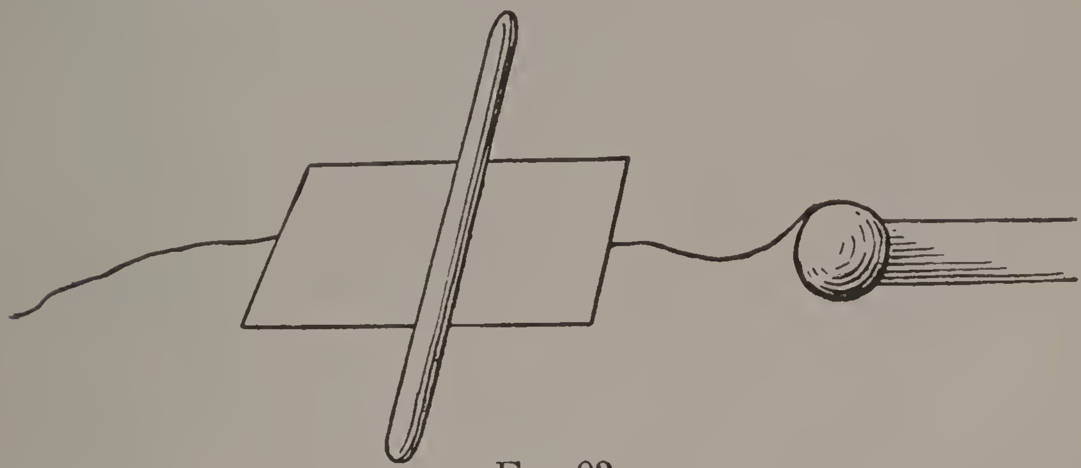


FIG. 93.

Draw a spark from the prime conductor as indicated in

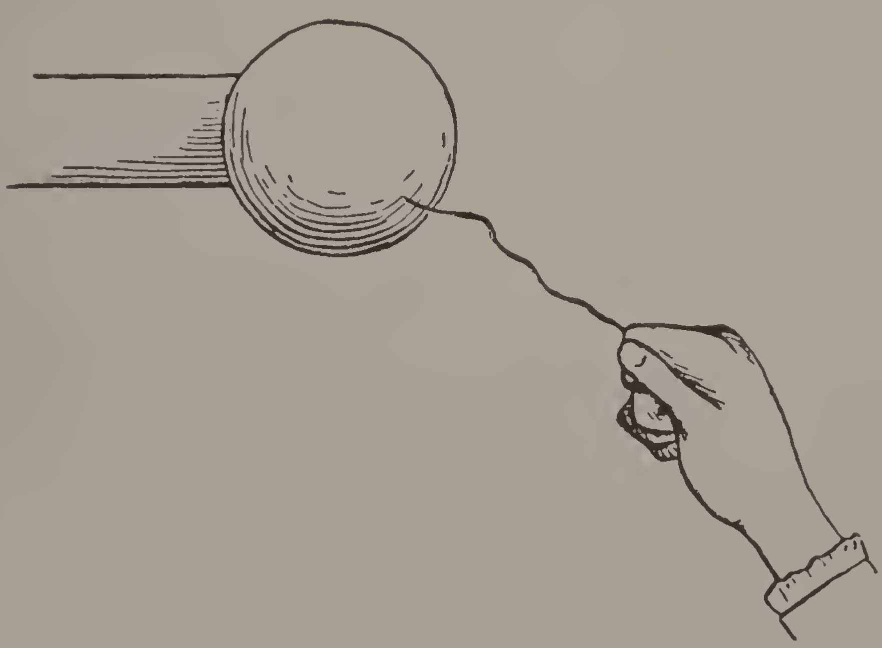


FIG. 94.

Write on a pane of glass with a sharpened stick dipped in thin glue. With care sprinkle iron filings on

the tracings. Observe the connections and breaks in the writing.

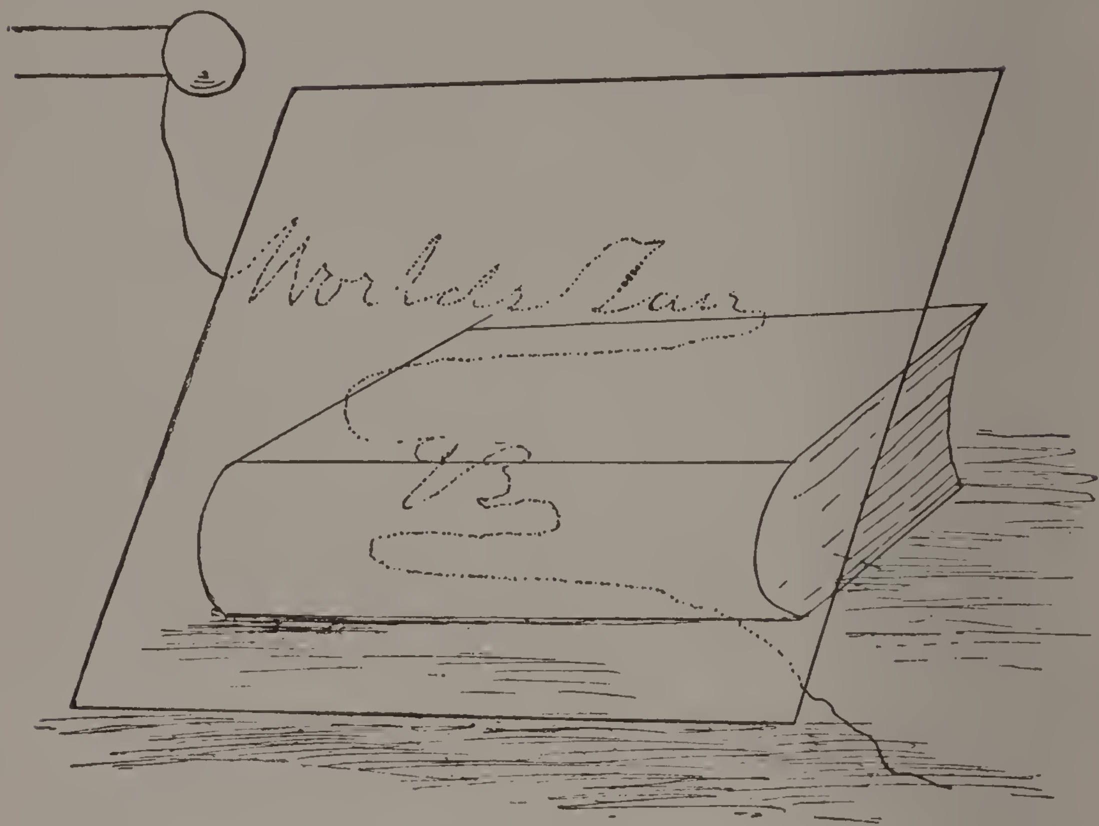


Fig. 95.

Support in a funnel fine dry sand. Connect to the electrodes of the electric machine.

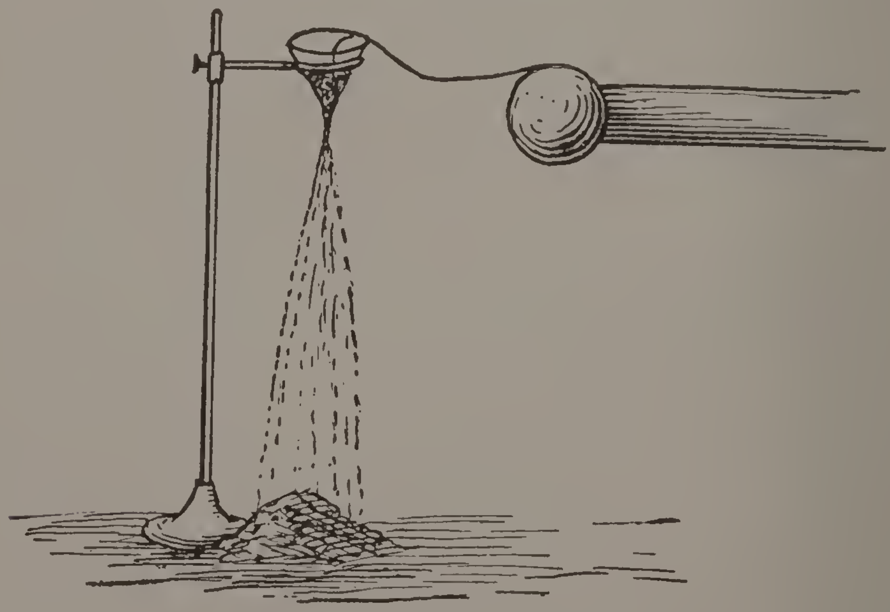


Fig. 96.

Fill a eudiometer with water and invert it over a shallow dish of water.

Pass into the eudiometer oxygen enough to cover the platinum wires.

Add twice as much hydrogen as oxygen.

Hold the tube firmly in position and pass the spark through the wires.

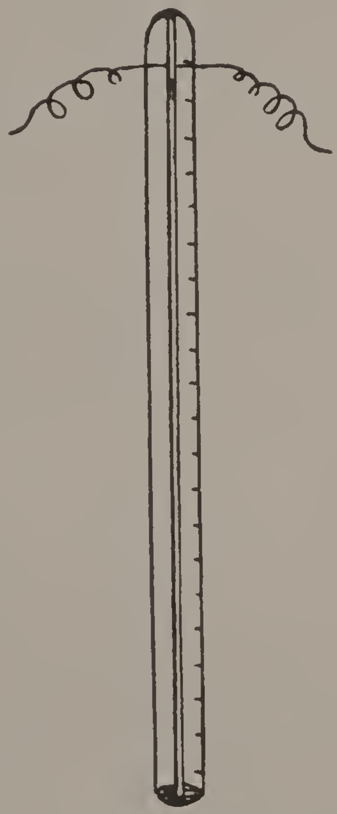


FIG. 97.

Pass a spark through a dozen pieces of sized paper and notice how many pieces have the double burr.

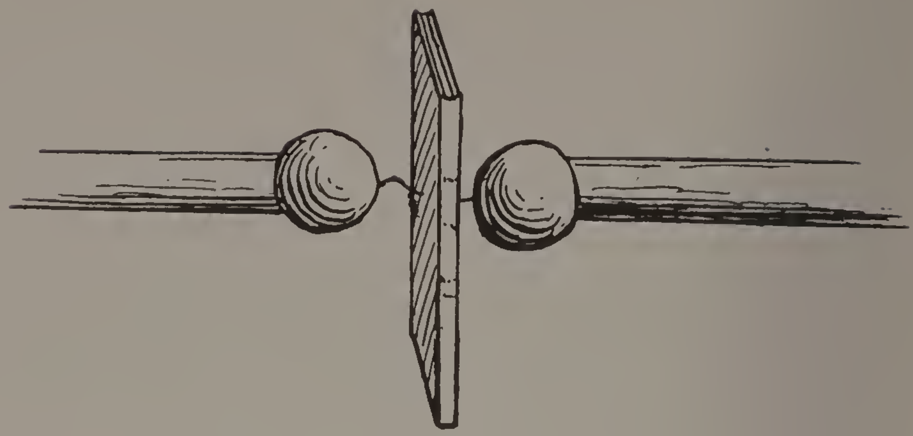


Fig. 98.

ELECTRIC DISCHARGE.

DEFINITION. The electric discharge is the neutralization of positive and negative potentials.

The discharge may be silent or take the form of

1. The spark.
2. The brush.

SILENT DISCHARGE. Silent discharge is the unobserved escape of electricity to surrounding bodies.

The experimenter is cautioned to be guarded on this point.

THE SPARK. The spark is incandescent matter having a vibratory motion of inconceivable velocity.

It may be spread out as in the illuminated pane, or form a succession of disks in Geissler Tubes, or be lengthened to several miles, as in lightning.

For the shape, color, length and duration of the spark, see Deschanel's Philosophy, p. 583.

THE BRUSH. The brush is a multitude of glowing lines of matter radiating from charged convex surfaces.

St. Elmo's Fire is a form of brush discharge.

The brush from the positive electrode is much finer than that from the negative.

EFFECT OF POINTS. Electricity is rapidly discharged from points and thin edges.

In the electric machine points are used to take up electricity from a charged body.

In ordinary experimentation, points and sharp edges are to be guarded against to prevent the escape of electricity.

CHAPTER XXVI.

ATMOSPHERIC ELECTRICITY.

The atmosphere, with the earth's surface, forms an immense Leyden jar.

The upper strata form the inner coating, the lower the insulating medium, and the surface of the earth the outer coating.

We move upon this outer coating and are thus enabled to see much of the electric phenomena above us.

This topic may be studied under the following points:

- I. Causes.
    - 1. Temperature.
    - 2. Conditions of vegetation.
    - 3. Resistance of air strata.
    - 4. Clouds.
    - 5. Winds.
- II. Lightning.
    - 1. Definition.
    - 2. Kinds.
        - a. Forked.
        - b. Sheet.
        - c. Globular.
    - 3. Direction.
        - a. To the earth.

b. From the earth.
4. Length.
5. Velocity.
6. Effects.
a. Disruptive.
b. Heating.
7. Rods.
III. Thunder.
1. Definition.
2. Clap.
3. Rumble.
4. Rattle.
5. Return shock.

For a mastery of the above outline, consult "Static Electricity," chap. xii. Atkinson.

ELECTRIC INDUCTION.

Give the etymology of the word.

Those best acquainted with electricity are unable to say what induction is.

This follows from the fact that scientific men have not yet agreed upon a definition of electricity.

Electric induction may be defined in a general way, as a process of developing electric phenomena by the approach of two unequally electrified bodies separated by an insulator.

All the experiments performed in Magnetism and Frictional Electricity have resulted from inductive processes.

INDUCTIVE EFFECTS. In the use of the electroscope the inductive effect of the electrified body was greatest when near the disk and least when far from it.

The difference in divergence of the leaves showed, approximately, degrees of inductive effect.

An electrometer shows this effect to vary in a constant ratio, thus establishing the law:

Electric induction varies inversely as the square of the distance.

INFLUENCE OF INSULATORS. Inductive effects are also influenced by the properties and arrangement of the molecules of the insulator.

Strain is produced upon these molecules by the presence of an electrified body.

This strain varies with the constitution of the insulator.

The efficiency of an insulator increases as its molecules resist strain, thus preventing the escape of electricity.

Hence the inductive capacity of an insulator may be measured.

A standard for inductive capacity is that of air at 32° F. and at a pressure of 29.92 inches of mercury.

The inductive capacity of all insulators is measured by this standard.

The ratio resulting from such a measurement is the specific inductive capacity of that body.

The following table may help the pupil to a choice of an insulator.

Dry air,	1.
Paraffin,	2.09
India rubber,	2.23
Shellac,	2.65
Glass (average),	5.87
Petroleum,	2.05

Instructive and valuable as are all experiments under frictional electricity, we are forced to admit that it plays a small part in the present practical applications of this subtle force.

CHAPTER XXVII.

DYNAMIC ELECTRICITY.

DEFINITION. Give the etymology of the word dynamic.

Dynamic electricity is electricity in motion.

It can exert power at great distances from its source.

The former terms used were galvanic and voltaic. Why?

Give a short sketch of the discoveries of Galvani and Volta.

What was the frog experiment?

Who performed it?

You perform it.

Pith the frog and then skin him and treat as in

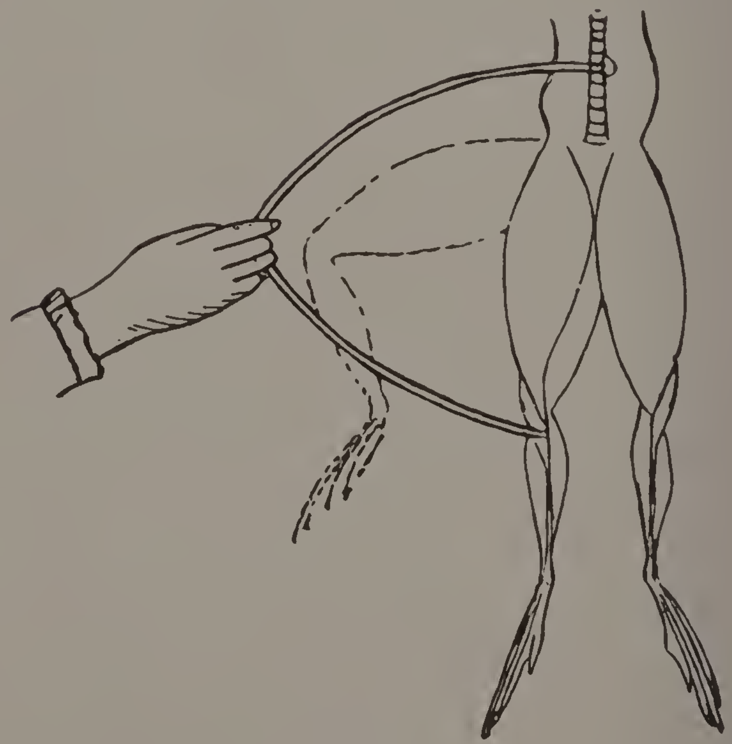


Fig. 99.

(Use narrow strips of copper and zinc.) Explain.

A GALVANIC BATTERY.

DEFINITION. **A galvanic battery is an apparatus for developing difference of potential by chemical action.**

It may consist of one or of many cells.

A single cell is called an element, and is shown in

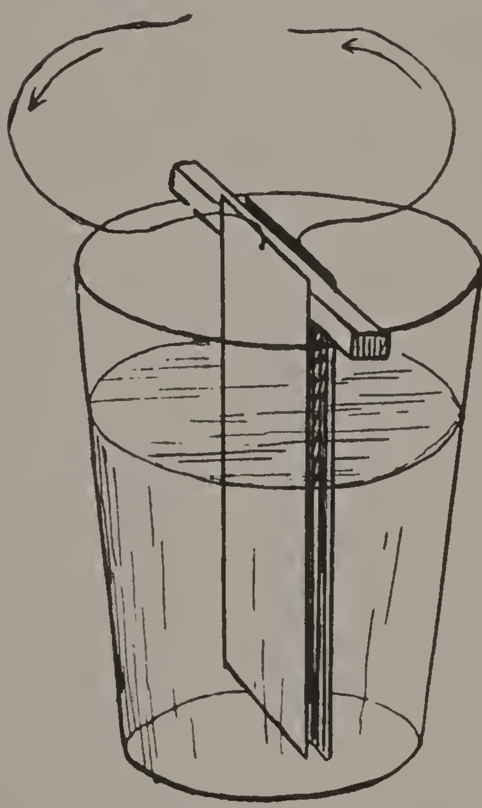


FIG. 100.

AN ELEMENT. **An element is a glass vessel containing an exciting fluid, usually acid, in which are placed two dissimilar metals.**

This element is a simple battery.

CURRENT. Suppose the metals are zinc and copper and the acid dilute sulphuric.

On joining the plates as shown, the zinc acts on the acid, but the copper does not.

(While the action is mutual, it is agreed, in chemistry,

that the metals begin it and hence rank first in all statements.)

This chemical action gives high potential at the zinc plate and a current of electricity is conducted by the liquid to the copper plate of lower potential.

From this, we see the zinc plate is called positive in the liquid and the copper negative.

In this action, water is decomposed and hydrogen bubbles appear at the copper plate and oxygen at the zinc plate.

Copper being a good conductor, the high potential it has received is carried to the air end of the plate, which is now called positive and marked +.

In accordance with Franklin's theory, stated elsewhere, electricity passes from a body of higher potential to one of lower, the former losing and the latter gaining.

Hence the air end of the zinc plate is called negative and marked −.

If the plates are joined as shown in the figure, a complete circuit is formed and chemical action continues.

But certain influences hinder the constant action of the battery, which will be considered under The Choice of Liquids.

Why do the ends of the plates bear opposite signs?

CURRENT. The term current is a misnomer.

There is no current,—no flow,—no visible movement.

Electric energy begins at a given point and is spent perhaps hundreds of miles away, a fractional part of a second being required for its transmission.

The most suggestive words are a "current flows."

If the thumb be thrust into one end of a hose that is filled with water and held as shown, water will issue from the other end at the same instant.

But the water that issues is not the water pressed upon.

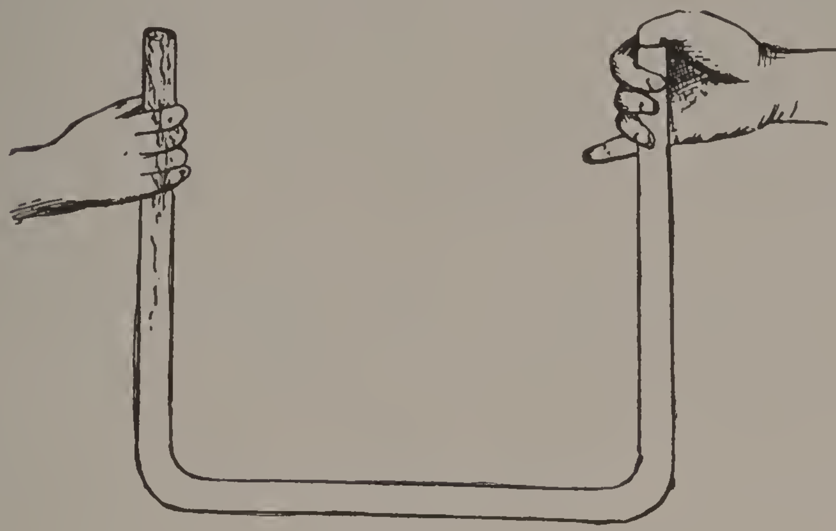


Fig. 101.

KINDS OF BATTERIES. Batteries have been multiplied until their names are legion.

Those in common use are:

The Gravity, Leclanche, Law, Diamond, Dry (Gassner's), and the Bichromate.

(The Dry Battery is a misnomer. There is no battery without water.)

The Bichromate Battery is the best adapted to experimental use and can be made by any one.

The Leclanche, Diamond, Law, and Gassner's are for open circuits, such as ringing call bells.

The Gravity is the one in universal use for telegraphy. It is used for closed circuits.

The only one pictured and described is the one the pupil is directed to make and use.

PRINCIPLES OF A BATTERY. 1. There must be two solids and one liquid.

2. One solid must act upon the liquid more than the other.

3. The greater the difference of chemical action, the stronger the battery.

BUNSEN'S CELL OR BICHROMATE OF POTASH BATTERY.

ITS CONSTRUCTION. 1. Choice of solids.

2. Amalgamation of zincs.

3. Preparation of carbons.

4. Choice of liquid.

CHOICE OF SOLIDS. In most batteries, zinc is one of the solids for three reasons:

1. It acts readily on all acids.
2. Its salts are very soluble.
3. It is cheap.

Before using the zinc plates, it will be best to amalgamate them—

1. To prevent local circuits because of impurities in the zinc.
2. To prevent waste.
3. To increase their conductivity.

The zincs are easily amalgamated by taking two nappies and into one of them pouring a pint of water and a tablespoonful of sulphuric acid.

Hold the plate upright.

FIG 102.

Pour the dilute acid on the plate turning it and changing its ends.

Change nappies and repeat.

All this is done to clean the plates.

Pour into the acid a teaspoonful of mercury and repeat all the former acts.

By adding four per cent. of mercury to molten zinc before casting into plates, no amalgamation is necessary.

The other solid is usually carbon for the following reasons:

1. It does not act on the acid.
2. It is a fair conductor.
3. It presents a large internal surface because of its porosity.

The carbon plate, so called, is really graphite and gas-carbon.

Carbon is too poor a conductor and too brittle to be used alone.

It is powdered and mixed with graphite, which is a good conductor, then made plastic with molasses, molded into plates about $\frac{1}{4}$ in. thick and of various sizes, and baked.

CUTTING THE PLATES. To cut a zinc plate, make a deep scratch by repeated strokes with the end of a file and pour a little mercury into the groove.

In about a minute, the plate becomes brittle along this line and may be safely broken.

To cut a carbon plate, lay a straight edge on the plate and make a groove with a scratch awl.

Turn the plate and make another over the first.

The plate will break easily along this line.

CHOICE OF LIQUID. There has been much experimentation to find a liquid that would do the following:

1. Excite the zinc after the action has begun.
2. Increase the conductivity of the water.
3. Absorb the hydrogen.

It has been found on trial that adding bichromate of potash to dilute sulphuric acid, secures all these results.

The acid decomposes the bichromate, liberating oxygen, which unites with the escaping hydrogen to form water, thus preventing polarization of the carbon plate by the accumulation of the hydrogen upon it.

The action of the zinc upon the sulphuric acid forms sulphate of zinc, thus:

$$Zn_2+2H_2SO_4=2ZnSO_4+2H_2$$

This coating of sulphate of zinc would soon polarize the zinc plate, but as all the salts of zinc are soluble, this salt is at once dissolved by the liquid and the plate cleaned for further action.

FORMULA FOR THE LIQUID. To one gallon of water add one and one-half pints of sulphuric acid and four ounces of bichromate of potash.

Mix in an earthen vessel—never in a glass one.

Stir well with a glass rod.

Set aside to cool.

SETTING UP THE BATTERY. For the pupil's use take two one-quart Mason's fruit jars and fill them two-thirds full of the battery solution.

Cut the plates $1\frac{1}{2}$ by 9 inches. Cut a piece of glass the same size to separate the plates.

Have two similar jars nearly full of water and into these set the plates.

Fasten connectors to the Zn and C for the attachment of wires.

This applies to each element.

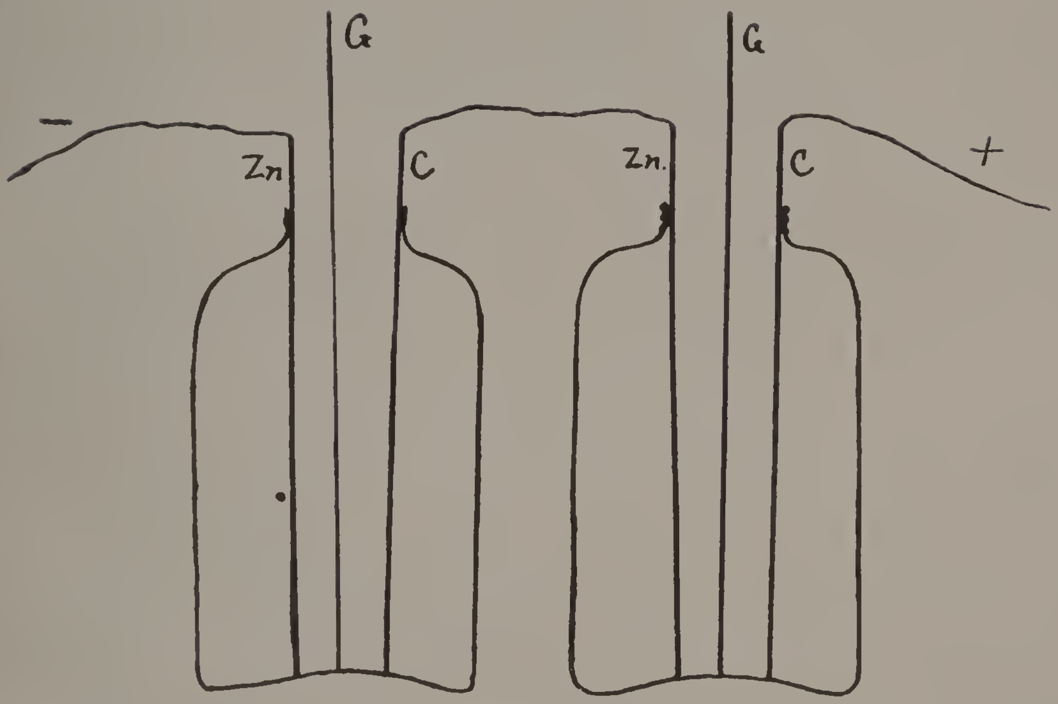


FIG. 103.

When it is desired to use the battery, lift the plates as shown, from the water to the battery jars and perform the experiment.

Immediately return them to the water jars for cleansing.

For convenience and heavier work, a battery may be set up as shown in

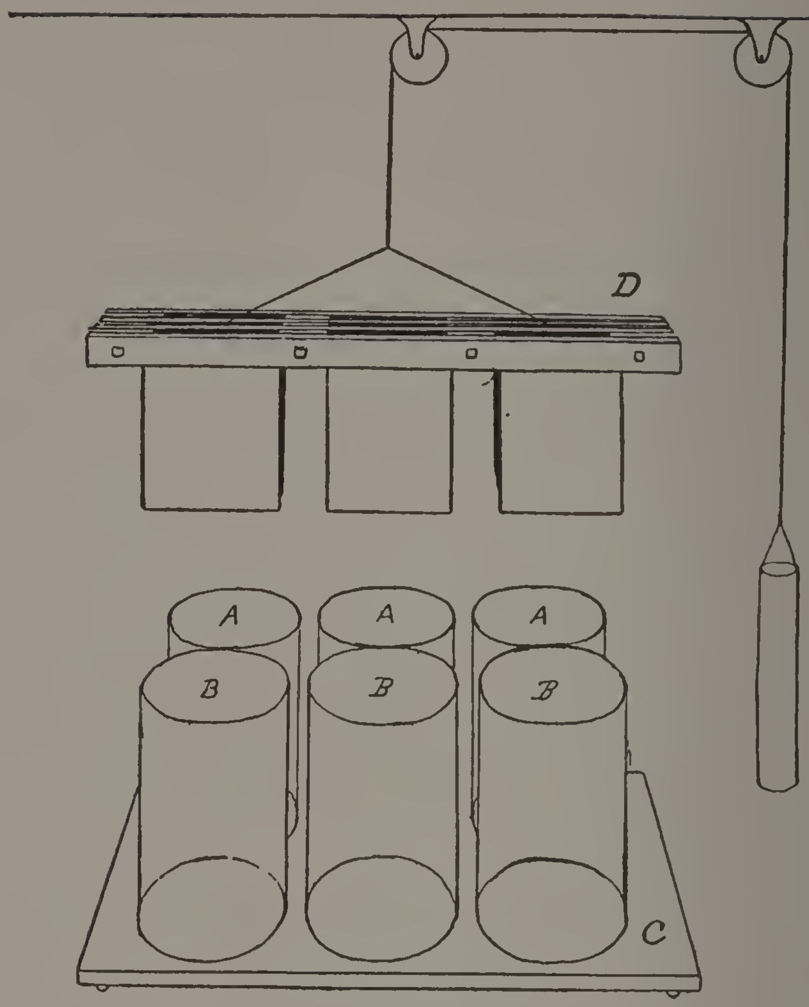


FIG. 104.

For experimental purposes, the bichromate of potash battery is the most efficient of any in use.

If set up as shown in Fig. 104, it may be immediately cleaned after using without the usual "mess" attendant upon the cleaning of batteries generally.

By having the jars on a sliding base the plates may be arranged for vertical motion only and the battery jars pushed back and replaced by the water jars.

On lowering the plates they are washed at once.

CARE OF BATTERY. In the care of the battery described the most important thing to do after use is:

1. To remove the plates from the solution.

2. To wash them at once.
3. To keep the zincs amalgamated.

TERMS USED. In the use of any battery, there are certain terms that may be new to the pupil.

Among these are: Cell, Electrode, Excitant, Poles, Conductors, Non-conductors, Insulators, Amalgamation, Polarization.

All of these have been explained.

There are other terms that will now be named that come under

CHAPTER XXVIII.

ELECTRIC MEASUREMENTS.

They are: Electromotive Force, Volt; Strength of Current, Ampere; Resistance, Ohm.

ELECTROMOTIVE FORCE. Electromotive Force or E. M. F. is the difference of electric potential.

It depends, in the battery, upon the kind of plates but not on their size.

The E. M. F. of the battery can be increased by joining the cells in series, Fig. 103, or decreased by joining them in multiple arc, i. e., uniting all the zincs for one pole and all the carbons for the other. Why?

THE VOLT. E. M. F. is measured in volts.

A volt is the unit of E. M. F. and is represented practically by the E. M. F. of the Daniell Cell.

STRENGTH OF CURRENT. The strength of the current is the quantity of electricity that flows across any section of the circuit in one second of time.

With a given resistance, it varies as the E. M. F.

THE AMPERE. The ampere is the current strength represented by an E. M. F. of one volt divided by a resistance of one ohm.

RESISTANCE. Resistance is that which opposes the flow of an electric current.

It is measured in ohms.

THE OHM. The ohm is the unit of resistance and is the resistance of a column of mercury .112— inches in diameter and 41.73 inches in length.

In practice, the ohm is the resistance of 250 ft. of No. 16, or 10 ft. of No. 30, copper wire.

ESTABLISHMENT OF UNITS. At a meeting of the International Electric Congress in Paris, in 1884, a system of Electric Units was established and is accepted as authoritative.

Those in most common use are: The Volt, The Ohm, The Ampere, The Watt.

The basis of the entire system is the Erg, which is a mechanical unit and represents the work done by the movement of 1 gramme 1 centimeter in 1 second.

Its symbol is C. G. S. These letters are the initials of centimeter, gramme, and second, which are the three factors of the Erg.

The following are some of the terms used, with their abbreviations.

E. or E. M. F. = Electromotive Force.
C = Current Strength.
P. D. = Potential Difference.
V = Volt.
amp. = Ampere.
R = Resistance.
I = Intensity.
R' = Internal Resistance.

r = External Resistance.
L = Length of Wire.
A = Area of Cross Section.
Om. = Ohm.
W. = Watt.
H.P. = Horse Power.

EQUIVALENTS AND FORMULÆ. 1 Erg = The Unit of Work.

10^7 Ergs = 1 W.
746 W = 1 H.P.
1 W = 1 V × 1 amp. or 1 Volt-ampere.

$$E = CR \text{ or } C(R' + r)$$

$$C = \frac{E}{R} \text{ or } \frac{E}{R' + r}$$

$$R = \frac{L}{A}$$

$$R = \frac{E}{C}$$

$$I = \frac{E}{L}$$

State the laws for each of the above formulæ.

It may be well for the pupil to know the names and uses of the following:

Voltmeter, Ammeter, Potential Indicator, Ohmmeter, Rheostat, Lightning Arrester, Wattmeter.

CHAPTER XXIX.

EFFECTS OF ELECTRICITY.

The effects of electricity may be classed under the following heads:

1. Electro-magnetic.
2. Electro-thermal.
3. Electro-chemical.

ELECTRO-MAGNETIC EFFECTS. On close inspection, it will be found that all the practical applications of electricity are wholly dependent upon its magnetic effects.

By this is meant, that, with possibly a single exception, the dynamo and the electromagnet are capable of performing any experiment in electricity.

Batteries are now used because they are convenient and cheap.

The applications of the electromagnet are:

1. Call Bells.
2. Fire Alarm.
3. Telephone.
4. Telegraph.
5. Induction Coil.
6. Dynamo.
7. Motor.

ELECTROMAGNET. **The electromagnet is a bar of iron or steel magnetized by lines of force from an electric current.**

If the bar is soft iron it becomes a temporary magnet.

If of steel, a permanent one.

The following experiment shows that lines of force surround a wire carrying a current and also leads us to see

how a bar of iron or steel may become magnetic from the presence of a current.

Pass a copper wire through a card and join the ends to the poles of a battery.

Sprinkle fine iron filings around the wire.

Gently tap the card.

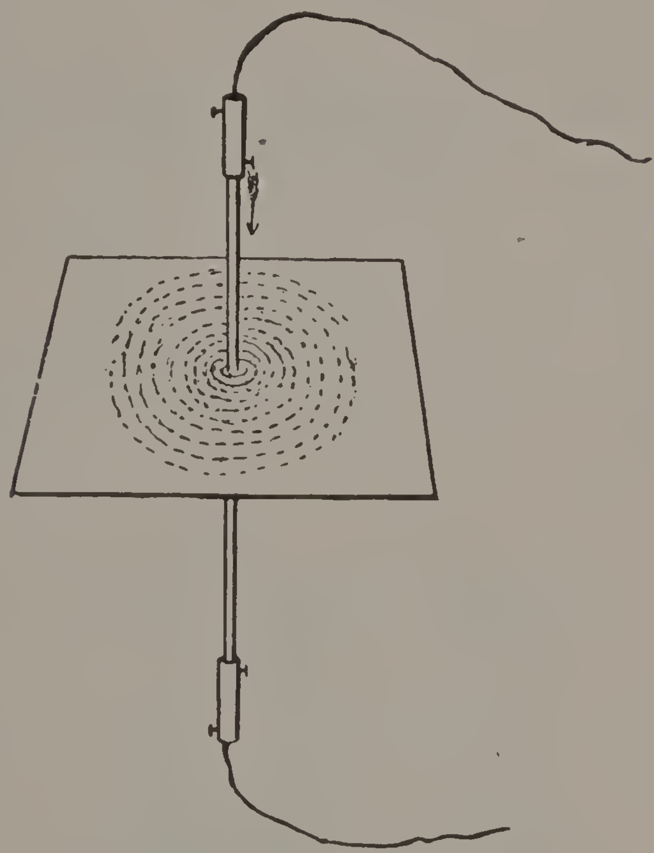


Fig 105.

Make a few coils of insulated copper wire around a steel bar and, with the current on, slide the bar through the coil from one end to the other several times, each time the same way.

Plunge one end of the bar into iron filings.

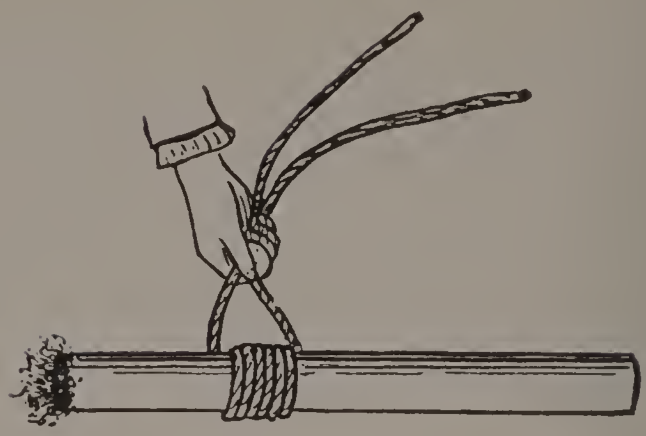


FIG. 106.

Turn off the current and most of the filings remain.

The magnet is a permanent one.

Bend a bar of soft iron 1 in. in diameter and 10 in. long in the form of a horseshoe.

Make the ends closely fit a plane surface.

Wind an insulated copper wire (Bell wire No. 16) around the bar, as shown in

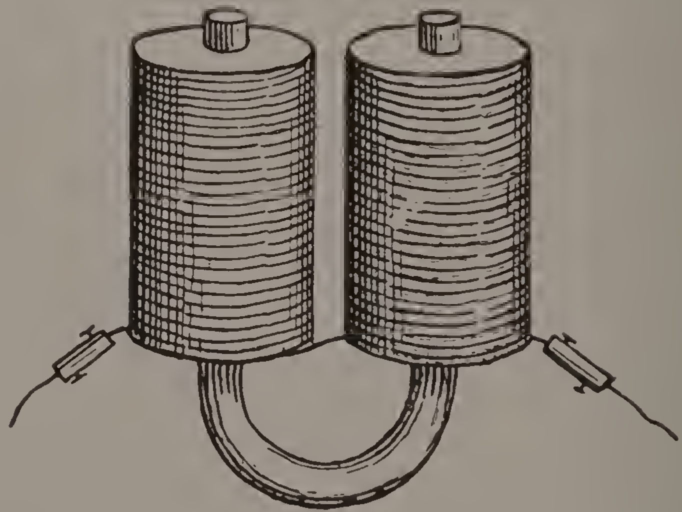


FIG. 107.

Close the circuit and apply to the iron filings as before. The filings cling to the bar.

Turn off the current and the filings fall.

The magnet is a temporary one.

The relative positions of the surface molecules of the bars were changed.

Those of the steel maintained the new relations, while those of the iron returned to the former ones.

In proof of this, take a very sharp razor and apply the magnet just made to the back of the razor, using a strong current.

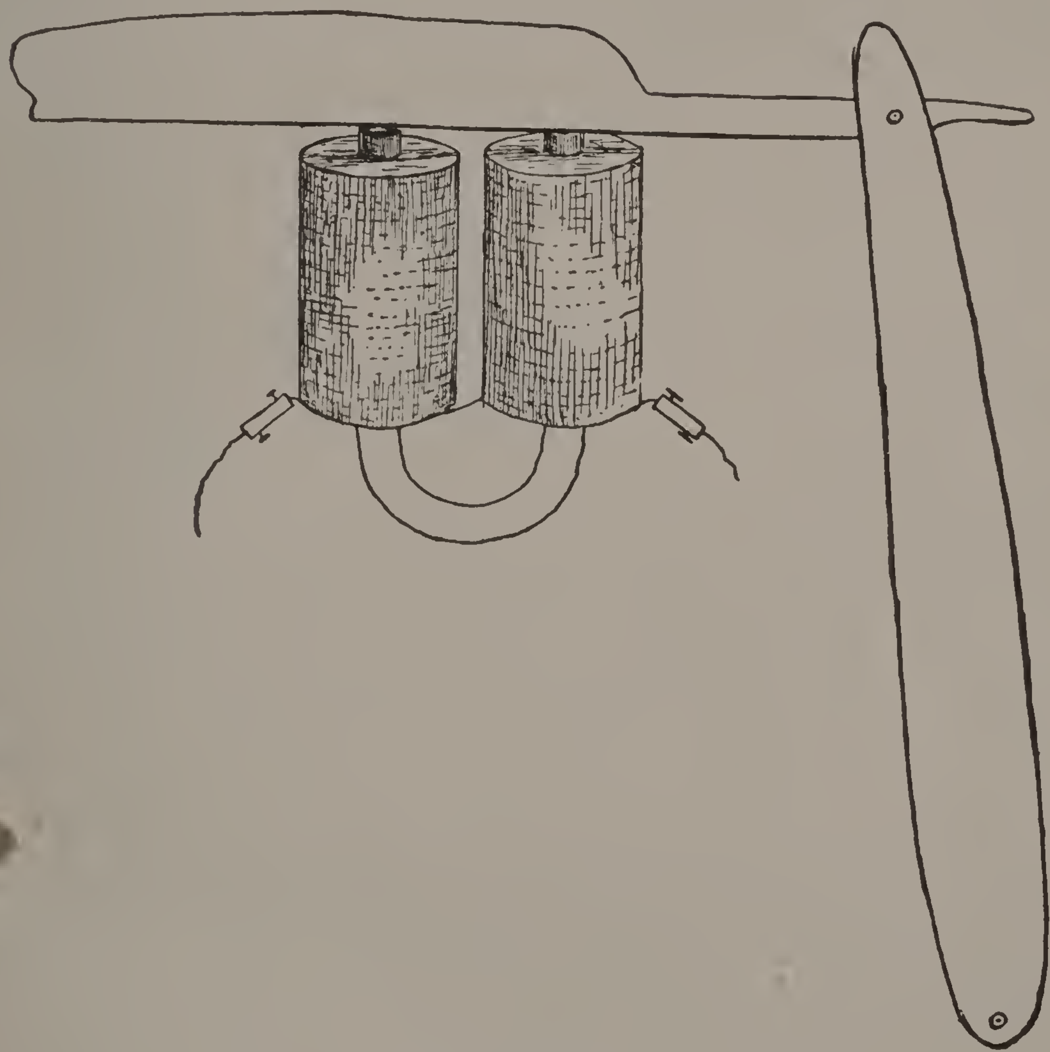


Fig. 108.

The razor will not shave as before. (Tyndall's experiment.)

The molecules are now faced about toward the ends of the blade and must be reset before using.

The razor is a permanent magnet.

Now use the electromagnet to lift pocket knives, needles, tacks, and other iron and steel objects.

Put an iron filing under your finger nail and withdraw it with the magnet.

What does this teach?

In any experiment in which the electromagnet is used to lift objects, will it instantly let go of them upon shutting off the current?

If not, it has residual magnetism.

To remove this property from common iron, treat as follows:

Place the iron rods or wires to be used for cores in a short steam pipe and put a screw cap on each end.

Keep this pipe red hot for six hours and cool slowly in ashes.

On removal of the iron, it will be found soft and nearly pure.

It has been decarbonized.

It will now act instantly if used as a core for a magnet.

If the pupil wishes a strong electromagnet he should make it short and stumpy, with the distance between the arms three times the thickness of one of them.

The wire wound on should not make the thickness of the coil more than three times the diameter of the core.

CALL BELLS. Annunciators in hotels and call bells in most dwellings exist because of the electromagnet.

A one or two-celled battery of the Leclanche type is screened from view and wires lead from this battery to the push-button and the bell. Some bells are rung by a miniature dynamo.

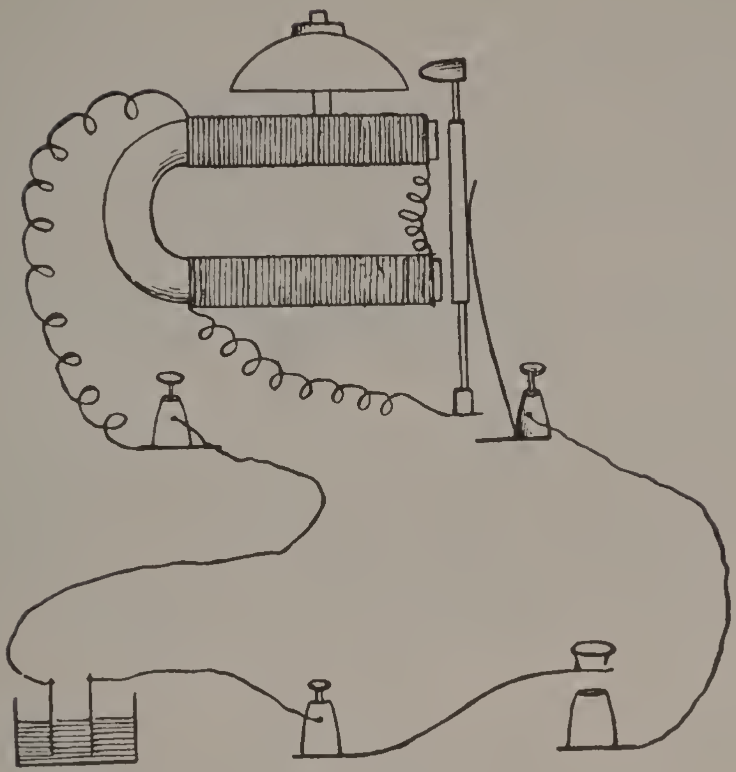


FIG. 109.

THE FIRE ALARM. The fire alarm is a signal given by a bell struck by the action of an electromagnet.

The two points of difference between it and the call bell are:

1. The push button is locked up and the key left near the Fire Alarm Box.

2. The bell at the engine house is a very large one and acted upon by a large magnet.

When the signal is given an annunciator in the engine house discloses the number of the Box.

All the connections are essentially the same as in Fig. 109.

SELF-ACTING FIRE ALARM. Signals may be given and the fire company appear upon the premises while the occupants of the building are unconscious of danger.

The self-acting fire alarm gives the signal by means of a thermostat.

A THERMOSTAT. **A thermostat is an instrument for regulating temperature by the unequal expansion of metals.**

It consists of an elongated glass bulb partly filled with mercury and having two short platinum wires enclosed in its ends.

These thermostats are placed on the ceiling of the room several feet apart, with wires joining the platinum electrodes to a battery.

When a fire breaks out in such a room, the heat being greatest at the ceiling, the mercury of the thermostat expands and completes the circuit and the signal is given.

A thermostat is usually set to complete the circuit at 110° F.

The pupil can easily make one.

Fig. 110.

Blow the glass bulb and melt the glass around a No. 30 platinum wire in one end as shown.

Pour mercury into the bulb until about two-thirds full.

Hold this bulb in water at 110 F. with the open end above the surface of the water.

Mark the surface of the mercury upon the neck of the bulb, after giving time for expansion.

Place a platinum wire in the open end of the bulb down to the mark and melt the glass around it.

To use this thermostat properly, connect to the battery and bell, Fig. 109, and warm gently with an alcohol lamp.

These thermostats are usually concealed by the last thin coat of plastering.

CHAPTER XXX.

THE TELEPHONE—THE TELEGRAPH.

THE TELEPHONE. The telephone is an instrument for impressing sound waves upon an induced electric current.

This is the transmitting instrument.

THE MICROPHONE. A microphone is an instrument by which minute sound waves impressed upon an induced electric current are made audible.

This is the receiving instrument.

CONDITIONS OF TELEPHONY. The conditions of telephony are:

1. An Electromagnet.
2. A Vibrating Disk.
3. A Yielding Insulator (at present, carbon).
4. A Conducting Wire.
5. A Battery.

A call bell is a necessary accompaniment of the telephone for exchanging signals.

The telephonic outfit is easy of construction for demonstration of the principles involved.

See "Physics by Experiment." (Shaw.)

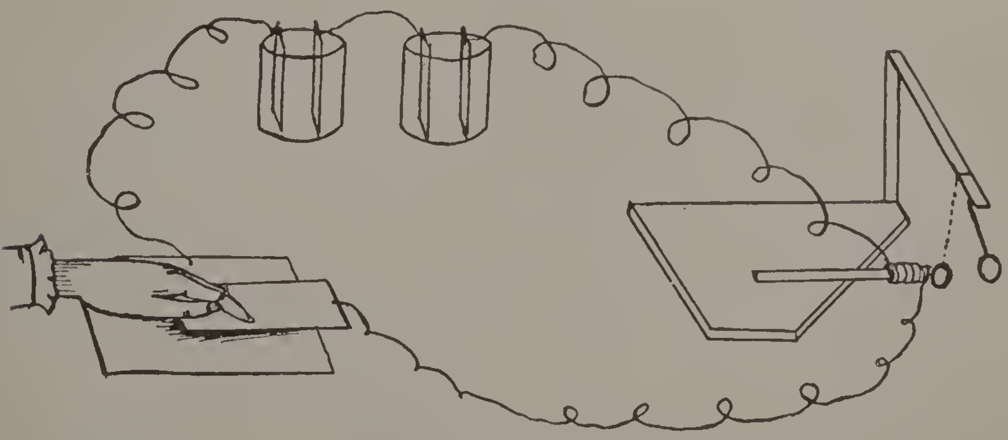


Fig. 111.

The telephonic current may be represented by a line of varying width.

The intervals represented indicate the effect of sound waves upon the passing current.

FIG. 112.

Evidently the instruments are duplicated at each station.

The telephonic circuit may be represented as in

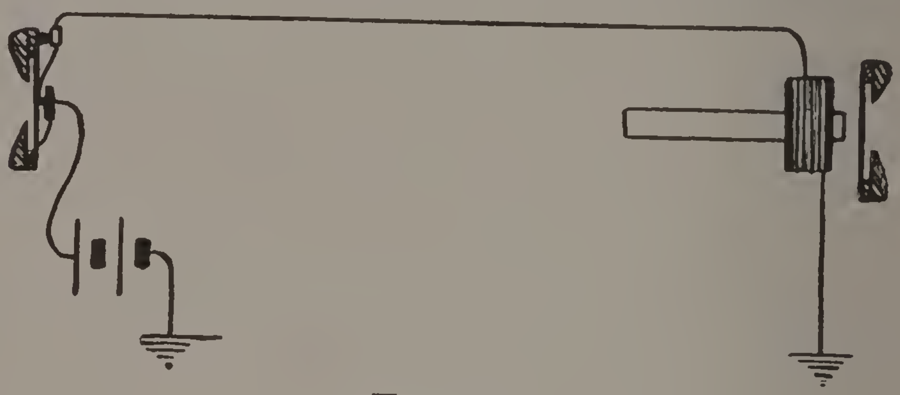


FIG. 113.

THE TELEGRAPH. The telegraph is a mode of communication by signals made by **interrupting** an electric current.

The conditions of telegraphy are:

1. A Transmitter or Key.
2. A Receiver or Sounder.
3. A Connecting Wire.
4. A Battery.

To the above is added the relay for long distance telegraphy.

The relay is a local battery to strengthen the effect of the sounder.

By making the circuit continuous on two different routes a relay may become a repeater.

In the English system of telegraphy, the message is read by the eye from the deflections of the needle of a galvanometer.

In America, the message is read by the ear from the clicking of the sounder.

The following figure represents the interrupted telegraphic current.

```
-- -   --   —-   --—   ——   —---   --—   ---

—--   --   —--     —-   - -   —     —--   --

---   -- -   - -   ---—   -   - --     -—   ——

-   - --   --   -- -   -—
```

Fig. 114.

Read the above message.

The Morse alphabet is as follows:

a	-—	j	—-—-	s	---	1	-——-
b	—---	k	—-—	t	—	2	--—--
c	-- -	l	—— -	u	--—	3	---—-
d	—--	m	——	v	---—	4	----—
e	-	n	—-	w	-——	5	———
f	-—-	o	- -	x	-—--	6	------
g	——-	p	-----	y	-- --	7	——--
h	----	q	--—-	z	--- -	8	—----
i	--	r	- --	&	- ---	9	—--—
						0	——

All operators must understand the same code of signals.

A great mystery in telegraphy is this: How can two messages be sent the same, or opposite ways, over the same wire at the same time.

If the same way, the system is called the diplex.

If sent the opposite way, the duplex.

In the diplex system two keys are used at the sending station and two sounders at the receiving station.

Two currents of unequal strength are used, giving the receiving operators, by their relays, signals of different intensity.

In the duplex system, when messages are sent simultaneously in opposite ways over the same wire, each operator controls the sounder of the other, but not his own.

Since simultaneous means to us at the same instant, as judged by our senses, and since electric movements are too rapid for such judgment, the exchange of signals is effected by each operator transmitting and receiving at the same time, each taking advantage of the intervals given by the other.

The following diagram from Gage's Physics will lead the pupil to see how messages are sent and what part the earth plays in the circuit.

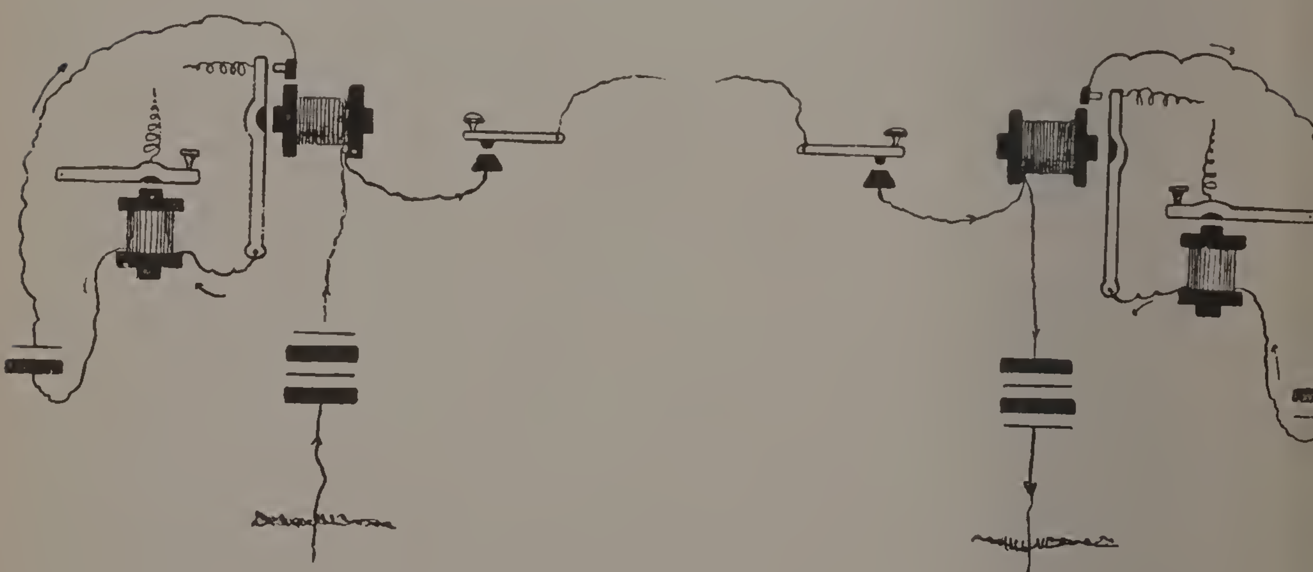


Fig. 115.

INDUCTION COIL. An induction coil is an instrument to increase the electromotive force of a battery.

For making, using, and experimenting with one, the pupil is referred to a small book on Induction Coils, How Made and How Used, published by D. VanNostrand & Co., N. Y. Price, 50 cents. Induction Coils. G. E. Bonney. Macmillan & Co., N. Y. Price, $1.50.

The accompanying drawing from Poyser's "Magnetism and Electricity" is given for its simplicity and for its value to a pupil in showing him how the parts of an Induction Coil are connected.

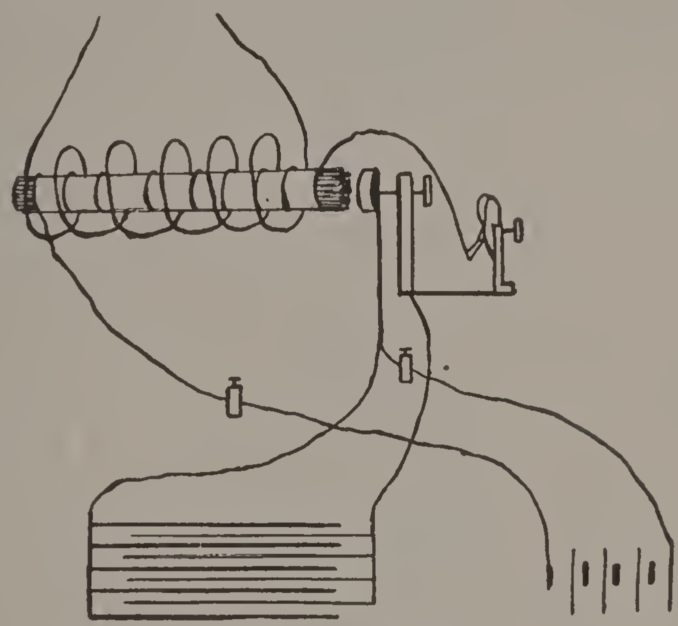


FIG. 116.

CHAPTER XXXI.

ELECTRO-THERMAL EFFECTS.

Among the wonders of electricity are its heating effects.

Electric Lights, Melting of Refractory Substances, and Welding, are modern phenomena.

The principle involved is:

That the arrest of motion produces heat.

The more rapid the motion and the more sudden the arrest, the higher the heat.

The rapid blows of a hammer upon a piece of cold iron may forge a horseshoe nail.

Electricity moves 288,000 miles per second.

If proper resistance be interposed to such velocity, the highest heat may result.

Connect the poles of a strong battery to a piece of platinum wire No. 30, and by the current bring the same to a red heat.

Bend the wire and dip it into a goblet of water.

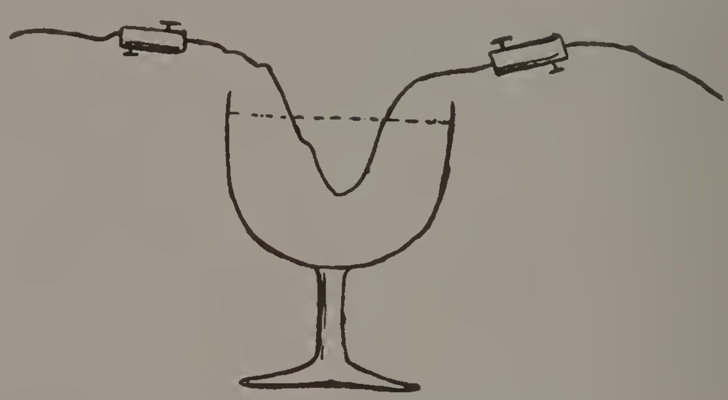


FIG. 117.

The platinum wire is a poor conductor.

The great resistance of the wire arrests the motion of the current and heat results.

On dipping the middle of the wire into the water, its ends are brought to a **white** heat. Why?

It is in the use of this principle that electric lighting has become practical.

THE ARC LIGHT. In this form of light two carbon pencils are interposed between the poles of a current from a dynamo.

Carbon offers high resistance to the current.

The pencil at the positive pole becomes shorter and

slightly concave, while that at the negative pole becomes convex and wastes less rapidly.

The particles of carbon carried across the arc glow at a white heat, and immediately unite with the oxygen of the air to form CO_2.

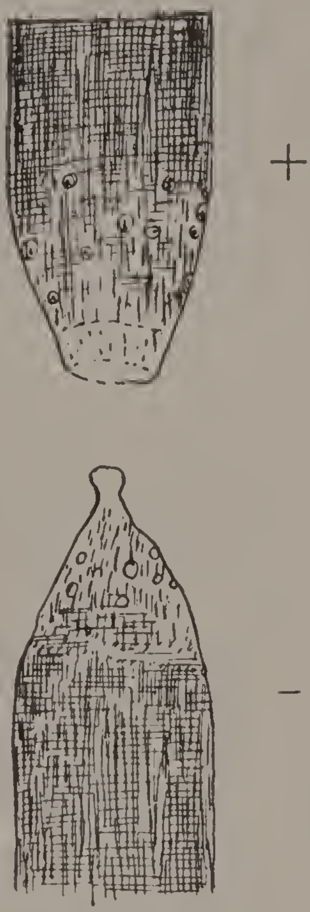


FIG. 118.

The distance between the carbons is controlled by a regulator operated by the current.

This regulator is usually above the light and moves the upper pencil only.

By a lever controlling the armature of an electro-magnet, a strong current separates the pencils and increases the resistance.

A weak current causes them to approach and lessens the resistance.

The effect of the regulator is to keep the pencils at about the same distance apart, but producing, at best, an unsteady light.

These lamps are pendant or placed on poles or masts.

If pendant, the number of lamps is increased, each illumines a small area with great intensity.

If the lights are elevated on poles or masts, the number is lessened, the area illuminated is larger, and the intensity of the light is less.

Increasing the number of lamps upon the masts lessens, but does not overcome, the difficulty.

The mast system is being discarded except for beacon lights.

Owing to the flickering of the lights, the imperfect composition of the carbons, and the daily cleaning of the lamps, they are plainly unfit for house use. Hence,

THE INCANDESCENT LAMP. An incandescent light is one that glows but does not consume.

After much experimenting, carbon filaments from the bamboo were found to offer high resistance to the current and to glow for days under its influence, providing they were in a perfect vacuum.

To obtain such a vacuum required a great outlay of time and capital.

By the use of the mercury pump, such a vacuum was obtained and the incandescent light became at once almost universal.

A metallic pump called the Berrenberg pump is now used to produce the vacua in incandescent lamps because of its rapid action and the perfection of its exhaust.

Both cylinder and plunger are metal. The vacua are free from the vapor of mercury and more nearly approach

the absolute vacuum than can be obtained by the mercury pump.

This pump exhausts 600 lamps in twenty minutes.

The life of an incandescent lamp varies from 600 to 800 hours.

The incandescent light is clear, steady, attractive, and is the cheapest light known, not excepting kerosene.

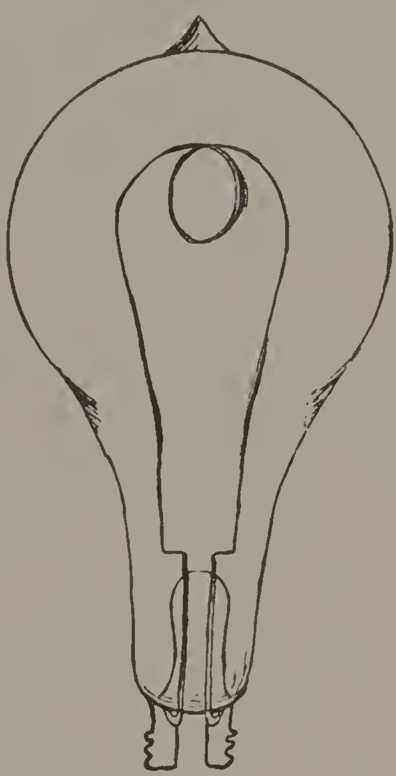


FIG. 119.

The heating effects of electricity are of great utility in firing explosives.

AN EXPLODER. A small copper cap filled with the fulminate of mercury has two insulated copper wires leading from it to the battery or dynamo.

This cap is placed in the powder or dynamite.

The length of the wires insures safety when the current is applied.

It is in this way that submarine blasting may be carried

on or that a marine torpedo becomes more dangerous than the entire armament of a man-of-war.

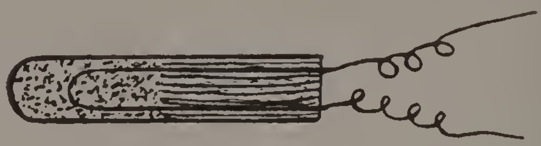


FIG. 120.

ELECTRIC WELDING. Welding by electricity is a simpler process than in the forge.

The usual way of welding is to "upset" the ends of the bars and lap them one upon the other.

Upon heating, the lap is reduced to the size of either bar by pounding.

Not so in electric welding.

The ends of the bars are rounded and pressed together.

A powerful quantity current is applied at the joint and the welding takes place in the center first.

All oxidised particles or impurities are forced to the surface which is welded last.

Bars one and one-fourth inches in diameter may be welded in forty seconds.

The bars become red hot only about two and one-half inches from the joint, the time of welding being too short for the heat to be transmitted farther.

This form of welding may be used when the heat of the forge can not be applied, and where the lap method is impossible.

Tubes, pipes, cables and wholly different metals can be welded by this process.

The welding of different metals is possible only when they can be given different degrees of heat.

The machine in use for this purpose is called a welder, the current in which is controlled by a treadle.

One bar is held rigid, while the operator forces the other against it by a lever.

What may be the outcome of this unexpected application of electricity to welding, soldering, and riveting, no one can predict.

CHAPTER XXXII.

ELECTRO-CHEMICAL EFFECTS.

The electro-chemical effects of electricity are such as overcome or establish chemical affinity.

They may be classed as :

1. Electrolysis.
2. Synthesis.
3. Electrotyping.
4. Electroplating.
5. Reduction of metals from solutions of their ores.
6. Storage Batteries.

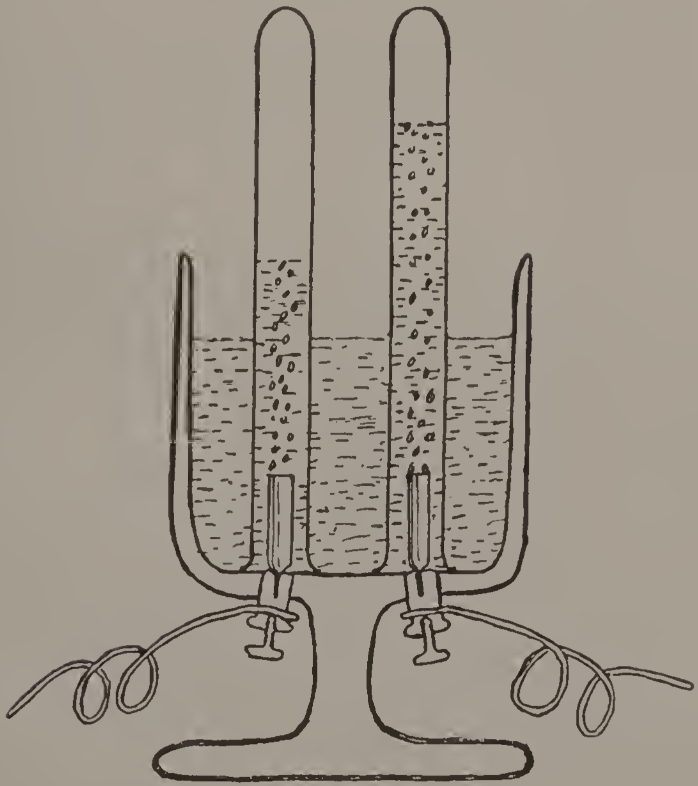


FIG. 121.

ELECTROLYSIS **Electrolysis is the decomposition of an electrolyte.**

An electrolyte is the liquid to be decomposed.

An electrolysis cup is a vessel in which decomposition by electrolysis takes place.

The electrodes are platinum terminals in the electrolysis cup.

The elements appearing at the positive electrode are negative and are called **anions,** those drawn to the negative electrode are positive and are called **cathions.**

OPERATION. Fill the electrolysis cup three-fourths full of water in which are a few drops of H_2SO_4 to increase its conductivity.

Fill the tubes with water and invert, without admitting air, over the electrodes.

Apply a current from a two-celled bichromate battery and watch the result.

Label the electrodes and the tubes.

Test the gases.

The process by which H is liberated at the negative electrode and O at the positive has never been seen.

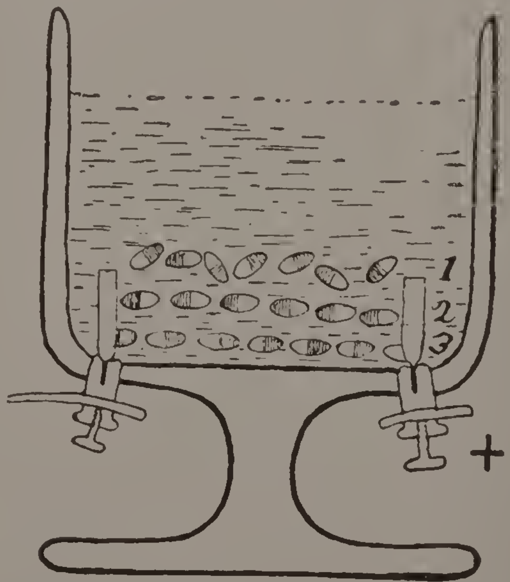


FIG. 122.

It is believed that the molecules of the water, like those of the magnet, lie in different directions as shown in Row 1 in Fig. 122.

On applying the current, the molecules are under stress and are polarized and appear as in Row 2.

From the continued effects of the current they exchange atoms, the O of the molecule next to the positive electrode becomes free and the water presses it upward.

Its H seizes the O of the next molecule, forming a new molecule of water.

Thus a series of decompositions and recompositions take place until the negative electrode is reached.

Here the H is set free and is pressed upward by the water

Examine Row 3.

The shaded parts represent H and the lighter parts O, in each oval figure.

This process is not known to be true, since by means of no device has the process here described been seen.

All other substances electrolyzed act in the same way, the metals appearing at the negative electrode and the non-metal at the positive.

This explanation is purely theoretical. It accords with the facts and is the one generally accepted.

If the poles are changed the gases change also.

PRINCIPLE. In electrolysis the metals are deposited on the negative electrode.

The above principle is the one guiding all the work in electrolysis, electrotyping, electroplating and in the storage battery.

Try a weak solution of table salt, sugar of lead, sulphate of copper, nitrate of silver.

An electrolysis cup in the form of a cell may be easily made.

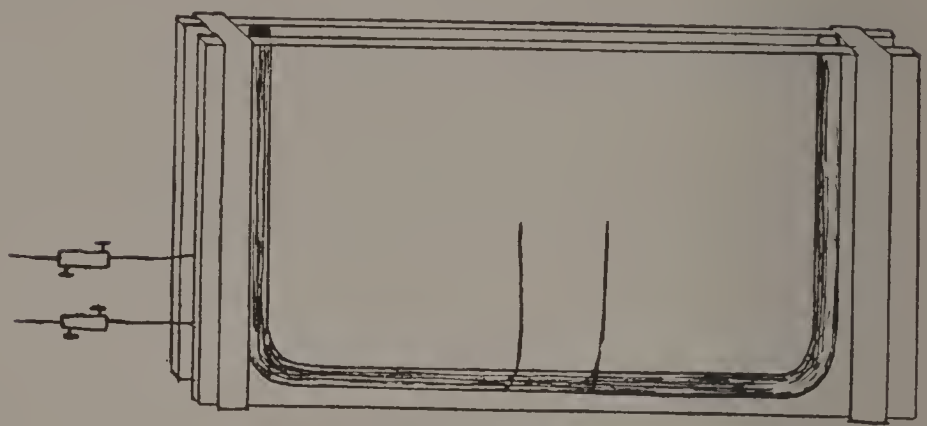


Fig. 123.

Use pieces of plate glass 3x4 inches and place a solid rubber cord between them as shown in Fig. 123.

Place No. 24 platinum wires on the cord about one-half inch apart.

Press the plates together and put on each end a band of tin one-fourth of an inch wide.

The wires will be pressed into the rubber. The projecting parts should be insulated from each other and brought outside the cord to the end of the cell.

Here they should be joined to the binding posts.

The wires may now be covered with marine glue or paraffin.

This cell may be used for all common acids, alkalies, and their compounds.

The best use of the cell is to show, by projection, electrolytic action on the screen.

SYNTHESIS.—**Synthesis, in electro-chemistry, is the formation of compounds by the action of an electric current.**

If the tubes over the electrodes for collecting H and O be united into one tube and wires inserted near the

top, the escaping gases mix and may be exploded by the electric spark.

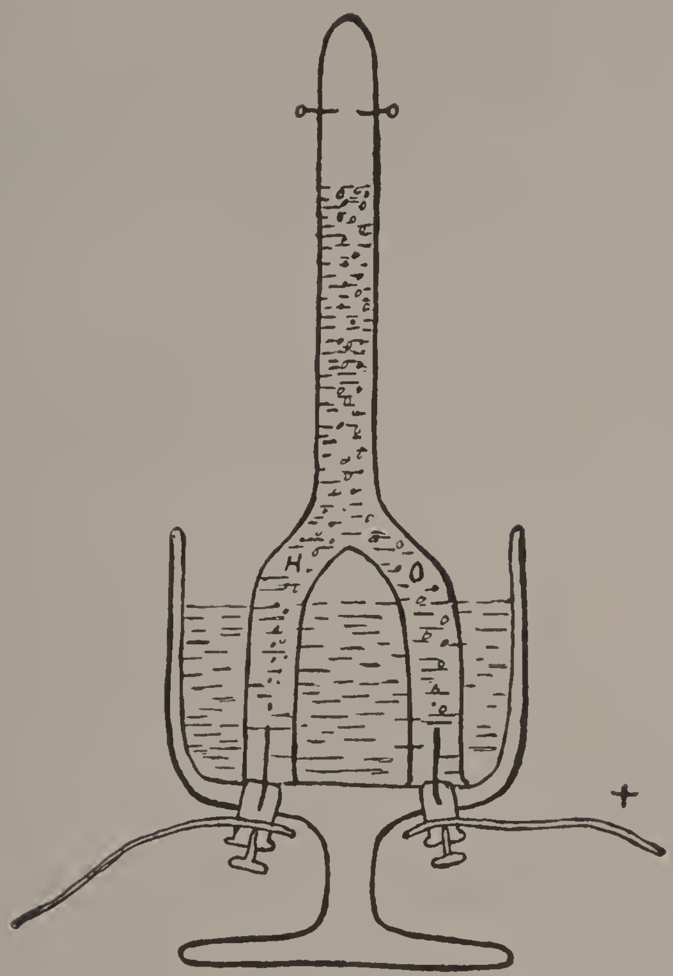


FIG. 124.

The tube now becomes a eudiometer.

The mixed gases should not occupy more than one-fifth of the space within the tube.

The heat of the electric spark restores the chemical affinity and water is formed.

Since chemical affinity in the battery developed a force that overcame chemical affinity in the molecules of the water, and since the force of the electric spark restored the chemical affinity between the gases O and H, it is proper to ask the question, Are chemical affinity and electricity identical?

Certain it is that chemical affinity always develops electricity and electricity *may* bring about chemical action.

They may be different names for the same force.

ELECTROTYPING.—Electrotyping is the process of making a metallic deposit by the electric current, upon a mold taken from type.

A wax impression of the type is taken and coated with plumbago.

This impression is now placed in a bath of sulphate of copper and joined to the negative pole of a battery or dynamo.

The positive pole is joined to a copper plate to keep the solution strong.

When the current is applied, a deposit of copper is made upon the plumbago.

The thickness of the deposit is about one-sixteenth of an inch.

The wax is then melted off and a backing of molten type-metal poured on.

These plates will give fine impressions for thousands of copies.

All of our standard books are printed from such plates.

The process of preparing these plates requires from four to twelve hours.

STEREOTYPE PLATES.—Stereotype plates, though not prepared by the electric current, may be described here because of their daily preparation and use.

Such plates do not give as good print or last as long as electroplates.

Our daily papers and cheap books are printed from stereotype plates.

Stereotype plates are prepared from type of special form.

Plaster of Paris or papier-mache is impressed upon the type.

When removed and dried, the cast is filled with molten type-metal which, after cooling, is removed from the plate.

The plate is planed to uniform thickness before using.

CHAPTER XXXIII.

ELECTROPLATING.

Electroplating is usually the process of depositing the more valuable metals upon baser ones, either for protection or ornament, or for both purposes.

The metals to be deposited are placed in solution forming a bath which is kept strong by the presence of the same metal in some form attached to the positive pole of the battery.

The articles to be plated must be perfectly clean, washed in acid, alkali, and water, and in no case touched by the hand.

On their removal from the bath, they have a dull rough appearance which is removed by burnishing.

Nickel has replaced silver for common articles because it is cheaper, harder and wears longer.

Almost anything can be plated by coating it first with some mineral or metallic substance that will take the deposit.

REDUCTION OF ORES. Since the introduction of the dynamo for lighting and motor power it has come to

play an important part in the reduction of ores and refining of metals.

The ores are roasted or pulverized and dissolved by the use of solvents and the metal deposited by electrolysis.

Aluminium exists in abundance in the common clays, but is difficult of extraction.

Aluminium compounds are fused in a carbon crucible.

Bauxite, a preparation of alumina or clay, is added.

A strong quantity current is applied to this fused bath and aluminium is drawn off and alumina supplied.

This metal has long been a chemical curiosity, but it is now a useful and ornamental article of commerce, due to the improved methods of extraction.

Aluminium is a ductile, malleable, bluish white metal, as light as glass, its specific gravity being 2.56.

Owing to its lightness and ready transmission of heat, it is thought that this metal will be much used in culinary arts.

STORAGE BATTERIES. Storage batteries are batteries which receive active electric energy and store it as cheminal energy.

Electricity cannot be stored. Its energy can.

Flowing water may turn a wheel that lifts a weight.

This weight has potential energy and may in turn do the work given it less the loss by friction.

But the water is not stored.

Storage batteries work upon the following principle: **Chemical potential is produced upon plates dissimilarly prepared by the electric current.**

Chemical energy is stored up in the friction match.

The phosphorus covers the sulphur which in turn covers the sugar that coats the wood.

A little friction fires the substances in the order named.

The chemical energy thus freed as heat about 600° F.

In like manner, electric energy is stored in the Faure battery.

Plates of sheet lead one-eighth of an inch thick are coated with a paste made of red lead and sulphuric acid on which is placed an insulation of felt.

These plates are rolled together and placed in a jar of water acidulated with sulphuric acid.

By electrolysis, the red lead is decomposed and sulphate of lead is formed on both plates.

Water is also decomposed and the escaping O forms dioxide of lead on one plate and the escaping H forms monoxide of lead, or as it is called, spongy lead, on the other.

On using the battery, the chemical reaction restores the sulphate of lead and the battery action ceases.

The charging of the battery consists in applying the electric current to the plates to change the sulphate to dioxide and spongy lead as before.

Improvements have been made in this process, but the high expectations concerning storage batteries have met disappointment.

Such batteries work with declining energy.

If continued force is required, the batteries must be duplicated so that while some are in use, the others may be charged.

They are objectionable on account of their great weight, a common cell weighing 130 lbs.

The duration of the cell depends upon its make, size and the work to be done.

CHAPTER XXXIV.

THE DYNAMO.

DEFINITION. **A dynamo is a machine which changes mechanical energy to an electric current.**

It is a modern invention, and, in its operation, is based on former discoveries embodied in the following

PRINCIPLES.

1 Magnetism and electricity may each be changed to the other by inductive action.

2. Mechanical energy may be changed to an electric current by such movement as causes the plane of a circuit conductor to cut a varying number of magnetic lines of force.

3. The direction of the current is at right angles to the direction of the inducing lines of force.

The intimate relation between electricity and magnetism was discovered by Jean Oersted, a Dane, in 1820.

In the same year, Arago and Davy, independently, discovered that electricity may be changed to magnetism, but to Michael Faraday is due the credit for discovering that magnetism may be changed to electricity.

He also discovered that mechanical movement of a circuit conductor in a magnetic field produces an electric current, thus proving that mechanical energy may be converted into current electricity.

The immediate result of this discovery was the first dynamo, October, 1831.

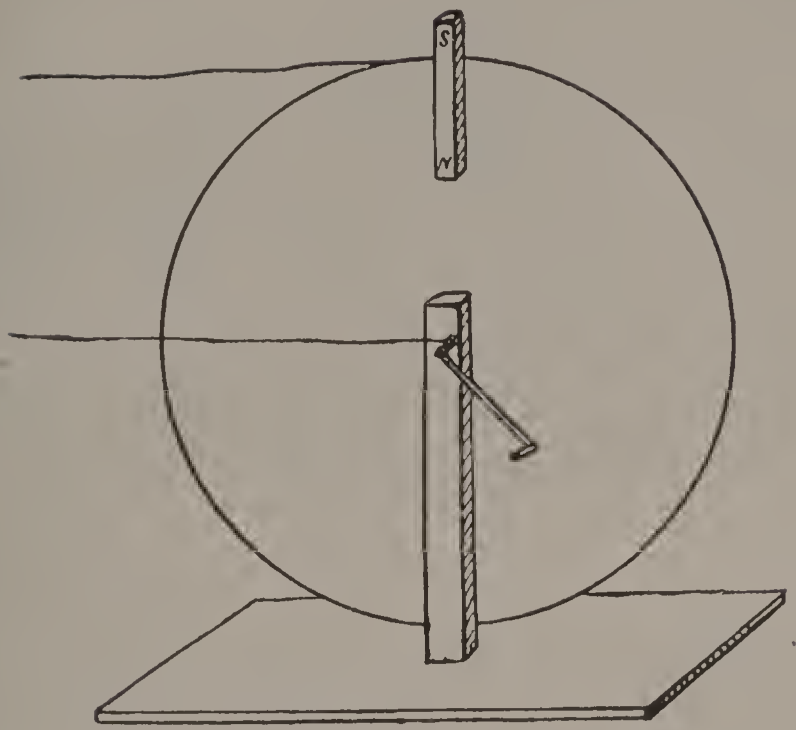


FIG. 125.

In the machine represented above the disk is copper.

The wires connect the axis and the edge of the disk to a galvanometer.

See also p. 17 in Electricity In Daily Life,

In the operation of the dynamo of the present, the conditions for effecting this change are.

1. A source of mechanical energy supplied, usually, by a steam engine.

2. The presence of powerful magnets.

3. A circuit conductor.

4. The rotation of one of either the magnets or conductor in the immediate presence of the other.

The manner of action as required by Principles 2 and 3 is illustrated in

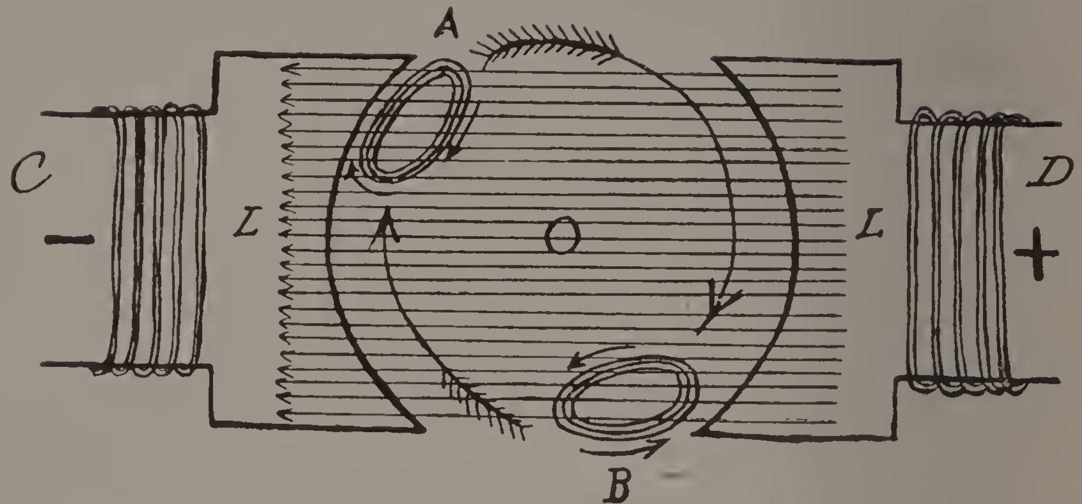


FIG. 126.

From the above drawing it appears that the plane of the rotating coil cuts more lines of force when in position A than when in position B.

It occupies, therefore, in each rotation positions of maximum and minimum magnetic potential.

The effect produced at each of such change of position, is a transitory current in the coil.

It will be observed also, that the direction of the current changes with the change of direction of the coil according to Principle 3, which is also stated in Lenz's Law, viz: the direction of currents induced by motion of a conductor or magnet is always such as to produce forces opposing the motion which generates them.

If these alternating currents are not changed in direction, the machine is called an alternating current dynamo.

Such currents may, however, be changed to a current of one direction by means of a commutator. The machine is then called a direct current dynamo.

It will be seen from this that there is from no dynamo a continuous current such as that from a battery.

The current is made as nearly continuous as need be by commutation and rapid succession of the transitory currents.

In the direct current dynamo, the result may be a current similar to the telephonic current, except that the waves occur at regular intervals.

From Principle 2 it appears that the current is generated by a variation in the number of lines of force cut by the plane of a circuit conductor in a given time.

From this it follows that the greater the number of such lines cut in a given time the greater the current strength. This may be further increased by an increase of the strength of such lines of force.

An increase in current strength effects an increase in E. M. F., the resistance remaining the same.

Since resistance in a conductor varies inversely as the area of its cross section, it is evident that the E. M. F. of the dynamo current may be varied by a variation in the number and size of the wires used.

Hence the strength of the dynamo current depends, primarily, upon the size and strength of its magnets.

It may also be varied by means of a transformer.

A Transformer is an instrument by which the E. M. F. of a current is diminished.

It is essentially an inverted induction coil, without the current-breaking apparatus.

It is evident therefore that it can be used only with an alternating current dynamo.

In use, its high resistance coil is connected with the dynamo and its low resistance coil with the lamp, or other circuit.

What is true of one coil is true of each of any number of coils that may be rotated.

Each coil adds its quota to the current at each passage from a position of maximum to one of minimum magnetic potential, and vice versa.

Hence it will be seen that quantity of current, or Amperage, depends primarily, upon the number of coils used, the number of maximum and minimum points of magnetic potential in each rotation, and speed of rotation.

Dynamos may therefore, by different arrangement of parts, be made to afford a current of high E. M. F. or Voltage, and small quantity of low Amperage, or on the other hand a current of high Amperage and low Voltage.

In electric lighting by use of the arc lamp, a dynamo affording a current of the former kind is used owing to great resistance of the lamps, while in incandescent lighting a dynamo affording a current of the latter kind is needed.

The essential parts of a dynamo are the field magnets, the armature, the commutator, and the brushes.

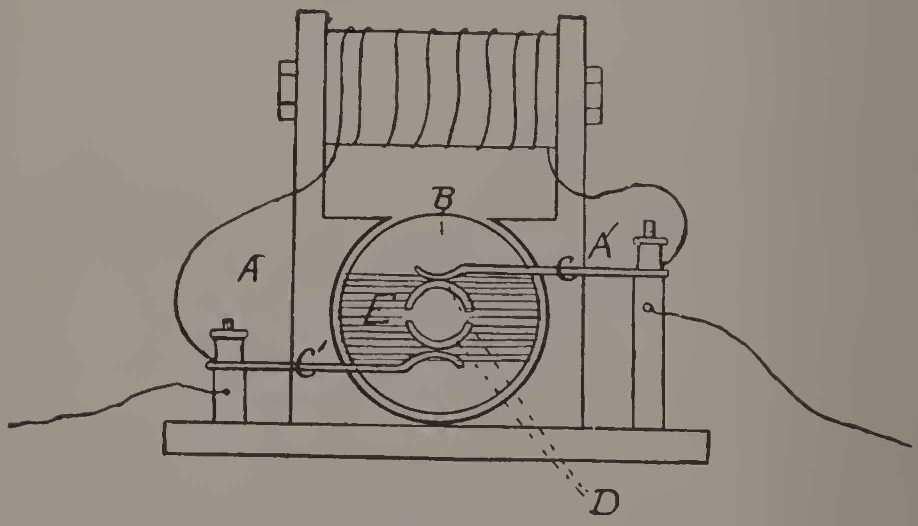


Fig. 127.

The field magnets are electro magnets except in small machines.

The armature consists of an iron ring, or cylinder, or framework of iron, upon which are wound the coils of insulated wire, the whole mounted upon a shaft for rotation.

The ring or cylinder of iron is called the core, and consists of layers of soft iron insulated from each other and from the shaft.

The core serves to lead the lines of force nearer the center of the armature and hence more certainly through the coils, since it offers less resistance than the air.

It also by reaction upon the surrounding field magnets increases the intensity of the magnetic field.

In a direct current dynamo each coil is connected to a bar of copper fastened upon the shaft and insulated from it and from each other.

These bars together form the commutator.

The coils may be connected to each other and to the segments of the commutator thus forming a closed circuit armature.

When the coils are independent of each other but are connected to the segments of the commutator they form an open circuit armature.

In an alternating current dynamo, the commutator is displaced by two flat metal rings mounted upon the shaft and insulated from it, to which the coils are connected and which serve as a means for collecting the currents.

In all machines, the currents are collected by means of thin layers of copper or layers of copper wires soldered together at one end and held in contact with the commutator or collecting ring at the other.

These are the brushes:—

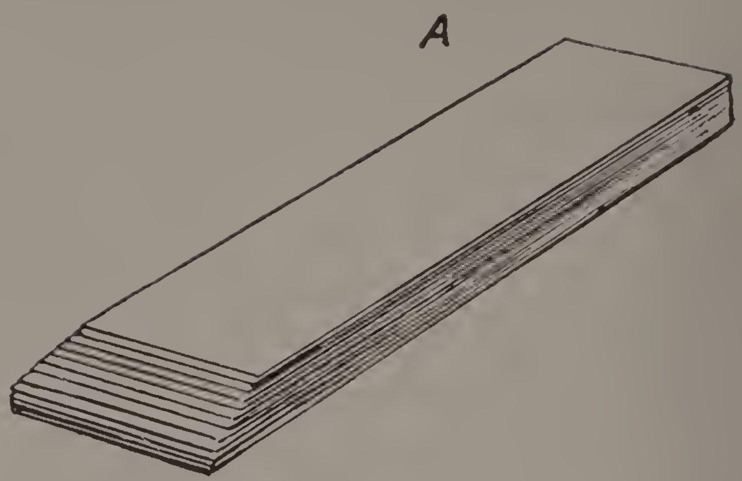


Fig. 128.

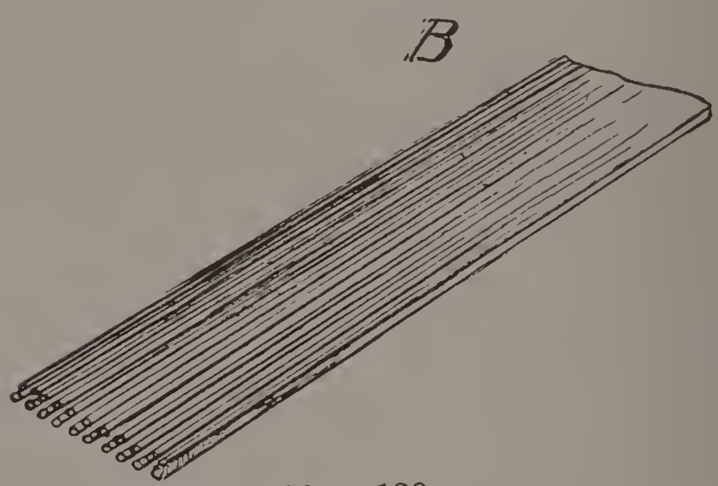


Fig. 129.

In the work of the steam engine, a variation in the energy needed to overcome a necessary variation in resistance is effected by means of a governor.

In the work of the dynamo, where steadiness is required the same end is reached by means of a shunt.

A shunt is a loop in an electric conductor.

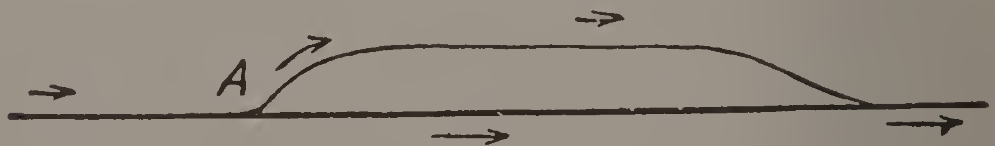


Fig. 130.

It is evident from the above drawing that the current will divide at the point A, and that the current travers-

ing the two parts of the loop will be inversely as the resistance of each.

The resistance in the shunt may be varied at will by means of resistance coils.

This shunt may have in it the field magnets of a dynamo.

It is evident from the above drawing that if there is introduced into the main circuit an increased resistance, such as the turning on of more lamps, the starting of electric cars or the passage of the same up hill there will be deflected to the shunt an increased current.

This increased current, traversing the coils of the field magnets, will, according to Principle 1, increase the magnetism of these magnets which will in turn, according to the same Principle, increase the electric energy to overcome the increased resistance.

Decreasing the resistance of the main circuit reverses these processes.

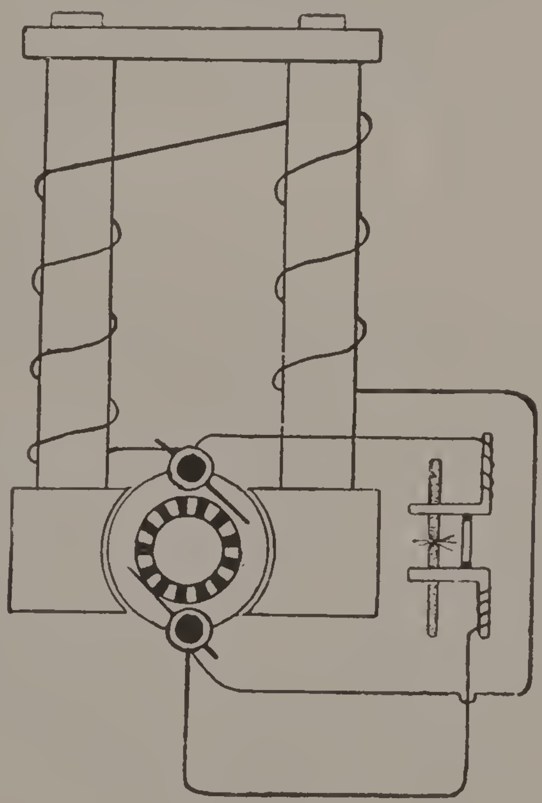


FIG. 131.

A dynamo whose winding includes a shunt is called a shunt wound or constant potential dynamo.

If the current traverses a single circuit, passing in series the armature, brushes, field magnets, and the external circuit, the dynamo is called a series wound or constant current dynamo. It is evident that its current varies directly as the resistance of the external circuit.

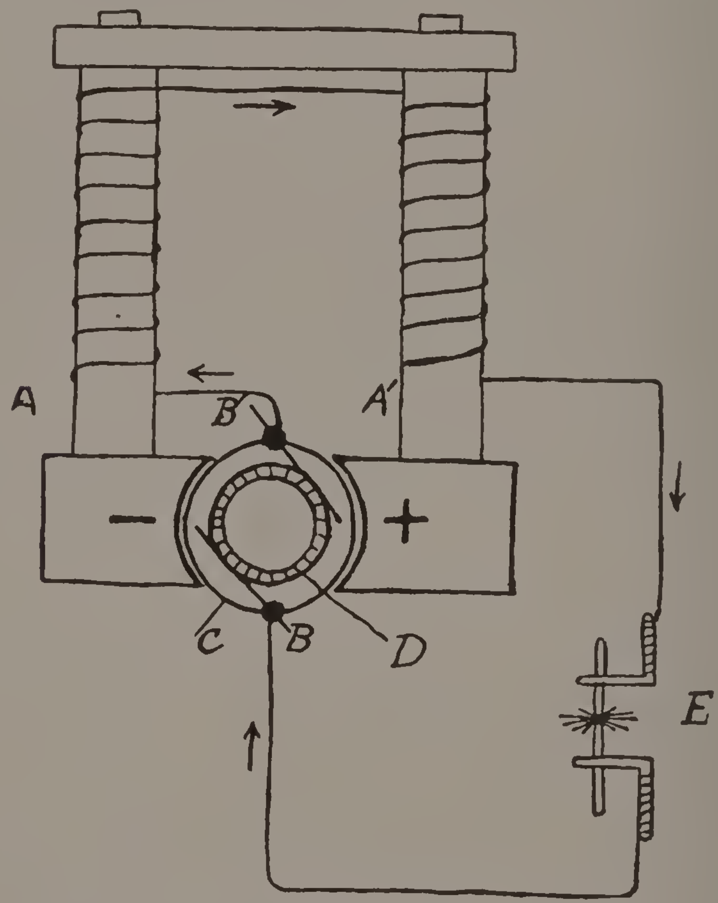


FIG. 132.

If the main circuit and shunt both traverse the field magnets, the dynamo is compound wound.

It is a constant potential dynamo.

The shunt may also include a small machine whose field magnets are permanent steel magnets, the current from which is used to excite the field magnets of the large machine.

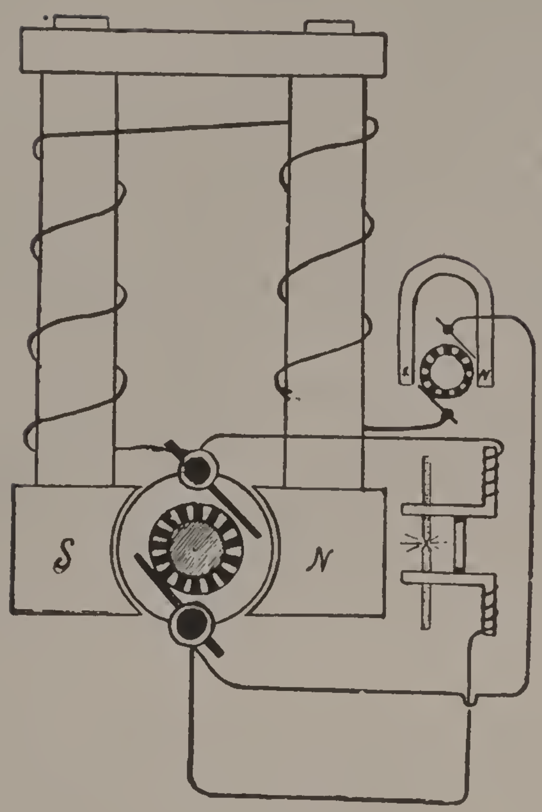


FIG. 133.

Separate excitation is accomplished also exclusively by means of a small electro-magnet machine, no part of the current of which passes through the armature of the large machine.

It is seen from what has been said concerning the action of the dynamo that next to mechanical energy, magnetism is an absolute prerequisite for the generation of an electric current.

Since in large machines the magnets used are electro-magnets, it may be asked, whence the magnetism with which mechanical energy begins the transformation?

It is found that the field magnets in process of manufacture, being constantly under the magnetic influence of the earth, become permanently magnetic to a slight degree.

This magnetism is called residual magnetism and serves to begin the action of the dynamo.

CHAPTER XXXV.

THE ELECTRIC MOTOR.

DEFINITION. An electric motor is a machine which changes an electric current to mechanical energy.

ITS PRINCIPLE.

Its principle is the converse of Lenz's Law, previously stated.

The mechanical energy applied in rotating the armature of a dynamo induces magnetism and electricity and consequent attraction, both magnetic and electric, which is a reaction in opposition to the mechanical movement.

It is clear then that if the mechanical energy is not sufficient to overcome this reaction the armature will cease to rotate, and that, minus loss by friction, the mechanical energy applied is a measure of the electric energy developed.

If two dynamos be connected, and mechanical energy applied to one it passes as electric energy to the other, producing the same conditions of potential difference and consequent reaction.

Since in the second machine nothing save friction opposes this reaction its armature rotates, but in a direction opposite to that of the first.

The mechanical energy required at the armature of the first is thus reproduced, less the friction of the two machines, by the armature of the second.

Since the friction of a motor or dynamo is only that of the

shaft of its armature, it is clear that these machines reproduce more of the energy given them than any other known machines, and is often more than 90 per cent. of it.

The dynamo made possible the motor, the motor makes possible the economical application of mechanical energy at points far distant from the point of its generation.

What may be accomplished in the future by use of these machines it is impossible to know.

THE ELECTRIC STREET CAR.

Beside the usual car and track the necessary conditions for street car propulsion by means of electricity are:

1. One or more dynamos.
2. A conductor, usually over the center of the track leading the current to the car.
3. A conductor, usually under the center of the track to which each of the rails is connected, leading the current from the car to the dynamo.
4. An electric motor to propel the car.

The conductors leading to and from the car are carefully insulated to prevent loss of electricity and accident.

The manner of operation is indicated in Fig. 134.

It is evident that the car completes the circuit between the conductors at whatever point it may be.

The armature in most of such motors makes about seven to ten revolutions to one revolution of the car wheel.

This change in rate of motion is effected by means of gearing, the change illustrating the general law of machines, that velocity may be exchanged for intensity, no loss occurring save by friction.

In the gearless motor, however, the armature makes the same number of revolutions, and the axle may serve as the shaft of the armature.

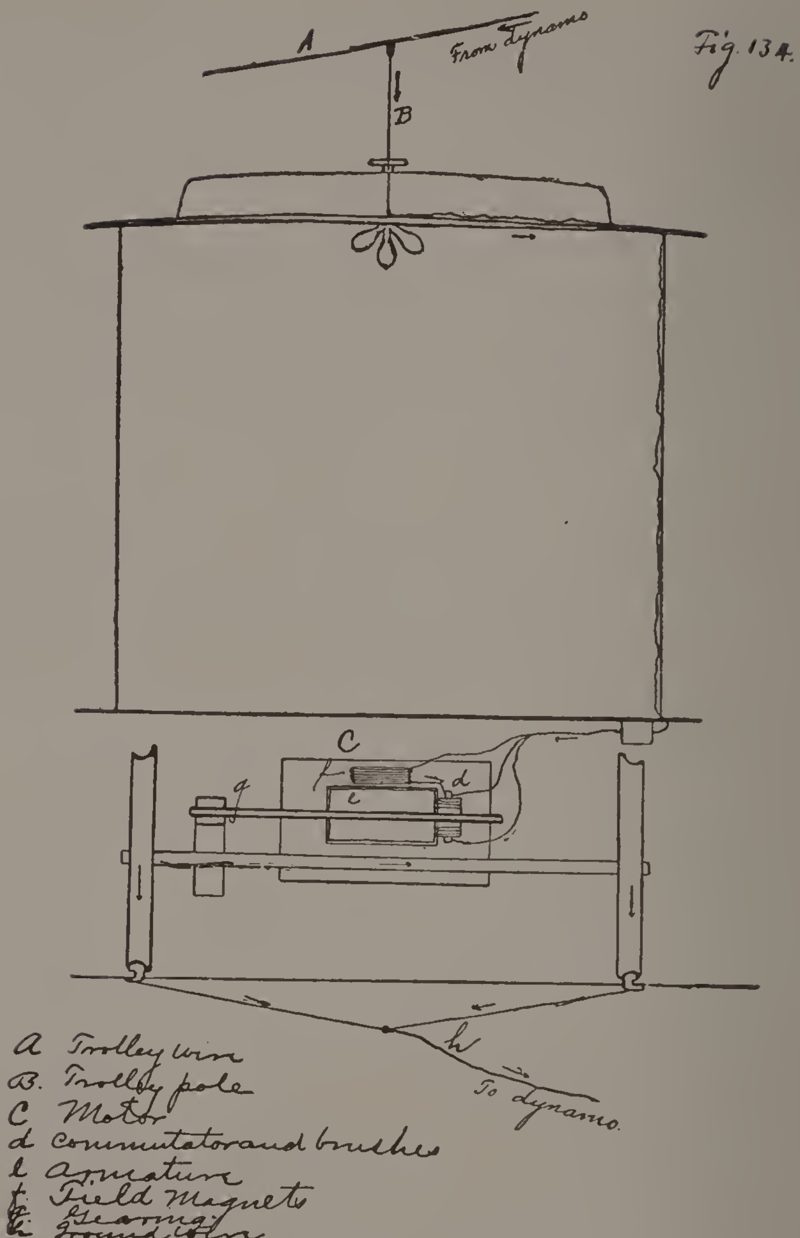


FIG. 134.

With it, greater dynamo strength is required, however.

The motor armature has as usual in the dynamo two brushes, one leading the current in and the other leading it out.

The motorman in controlling the movement of the car changes its direction by changing the entering current from one of the brushes to the other, as it passes through the motor.

This change is effected by means of a switch controlled by a lever.

In going up grade or in starting the car the amount of energy is controlled by means of a rheostat which is operated by a lever.

A rheostat is an instrument by means of which a resistance, varied at will, is opposed to the passage of an electric current.

To stop the car, the motorman breaks the circuit between the conductors at the rheostat, and uses the brake.

The switch and rheostat are placed under the car. The levers operating these and the brake are on the platforms at the ends of the car.

It has been seen that by means of the motor an electric current may be changed to mechanical energy.

In the passage of an electric car down a grade or hill the current is turned off, but the forward motion of the car keeps the armature of the motor revolving.

The motor is now a dynamo for it now receives mechanical energy from the effects of gravity, and hence generates an electric current.

This electric current produces a consequent magnetic and electric attraction, which in accordance with Lenz's Law operates to oppose the motion of the car.

The motor thus operates as a brake.

THE END.